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# WELCOME



Just over 150 years ago, the monk Gregor Mendel presented his findings on how traits could be passed down from parents to their offspring, following his research on pea plants in his monastery garden. He seeded the idea of genes – a coded set of biological instructions passed on from one generation to the next. But it would be 135 years before scientists could fully decipher this code, with Tony Blair and Bill Clinton

announcing to the world that we had unravelled the blueprint of human life at the turn of the millennium.

Today, in an emergency, labs can sequence a patient's genome in just 26 hours. You can even get your own genetics (partially) transcribed for under £125. The proliferation and speed of genome-sequencing technology has created an ever-growing treasure trove of data that scientists have been plundering for the last decade, pinpointing the faulty genes that make us sick. Now it seems that genetic research is entering the next stage. Scientists are on the hunt for the genes that keep us healthy: the ones that keep a lucky few safe from inherited diseases that have ravaged their families. Discover the whole story on p34.

Finally, if you're reading this before – or even on – your holiday, turn to p60. Turbulence always gets my palms sweaty, but next time I feel an in-flight judder I'm going to think about that image of the plane's wings, take a deep breath and relax.

*Daniel Bennett*

Daniel Bennett, Editor

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Does a quirk of your DNA make you immune to certain diseases? Science writer and broadcaster Kat give us the lowdown on the hunt for the genetic superheroes. And yes, you could be one... → p34



### CHERIE CHENOT-ROSE

Some science jobs are not for the faint-hearted. We speak to six people with some of the most extreme jobs in science, including Cherie, the founder of the American Crocodile Education Service. → p44



### BRENDAN KELLY

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## WHAT WE'VE FOUND OUT THIS MONTH

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PHOTO: ANDY POTTS



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# Holy moly!

MIRNY,  
EASTERN SIBERIA

In eastern Siberia, a yawning void appears poised to engulf the town of Mirny. The open-pit Mir diamond mine is also known as 'the navel of the Earth'. It is one of the largest human-made scars on the surface of the planet, measuring 525 metres deep and 1,200 metres across.

The mine, which closed in 2004, contains a rock called kimberlite. Kimberlite forms from magma deep in the Earth's mantle; as the magma works its way to the surface, it collects pieces of diamond-bearing rocks, before erupting as a volcano and hardening into giant underground 'pipes'.

"About one in 100 kimberlite pipes contains gem-quality diamonds and only a very small proportion of these contain sufficient quantities of diamond to support economic extraction," says Dr Cherry Lewis from the University of Bristol's School of Earth Sciences.

Workers at the mine burrowed into one of these pipes and yielded around £13bn worth of diamonds over the mine's lifetime. At its peak in the 1960s, 2,000kg of diamonds were being excavated a year, 20 per cent of which were of gem quality – a large output, even for a mine of its size.

PHOTO: GELIO.LIVEJOURNAL.COM











EYE OPENER

## Catching clouds

CENTRAL FLORIDA,  
USA

Thunderclouds glower behind Red Bull Air Force athlete Sean MacCormac as he navigates his board through the Florida twilight, plummeting at up to 209km/h (130mph). Known as sky surfing, this sport attracts the keenest free-fall enthusiasts.

Despite its name, sky surfing is closer to skydiving than surfing, as the drag caused by the body and board must be considered to stay in control. With his feet strapped in place, Sean needs incredible strength and skill to maintain his centre of balance. The slightest lean in the wrong direction could cause him to spin so rapidly that he would lose consciousness.

It would be a tough enough feat during calm conditions, but MacCormac leapt out of the plane during a thunderstorm. He needed to steer precisely along the edge of the crackling clouds, but never into them. Sub-zero temperatures, unpredictable air currents and lightning lurk inside the clouds. Thankfully, he touched down unscathed 3.2km below. All in a day's work for an extreme athlete...

PHOTO: SEAN MACCORMAC







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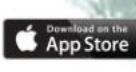
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# DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

SEPTEMBER 2016

EDITED BY JASON GOODYER



BIOLOGY

## DOLLY THE SHEEP'S SISTERS ARE AGEING JUST FINE

*Four of Dolly the sheep's siblings are celebrating their ninth birthdays in rude health, suggesting cloned animals don't suffer from premature ageing as previously suspected*

Happy birthday to ewe, happy birthday to ewe, happy birthday to ewe, happy birthday to ewe, happy birthday to ewe



**"WE FOUND  
THAT OUR  
CLONES,  
CONSIDERING  
THEIR AGE,  
WERE  
HEALTHY"**

**Say 'Hi' to Debbie,** Denise, Dianna and Daisy, four sheep cloned from the same mammary gland cell line as Dolly. They have just passed their ninth birthdays, disproving a widely held belief that cloned animals suffer from premature ageing.

Dolly was put to sleep in 2003 at the relatively young age of six, because tumours were found

growing on her chest. This led some researchers to believe that animals cloned using somatic-cell nuclear transfer, or SCNT for short (see box, right), might age more quickly than their natural-born counterparts – but no one knew for certain.

"Healthy ageing of SCNT clones has never been properly investigated. There have been no detailed studies of their health," said researcher Kevin Sinclair of the University of Nottingham. "One of the concerns in the early days was that cloned offspring were ageing prematurely and Dolly was diagnosed with osteoarthritis at the age of around five, so clearly this was a relevant area to investigate. Following our detailed assessments of glucose tolerance, insulin sensitivity, blood pressure and musculoskeletal investigations, we found that our clones, considering their age, were at the time of our research healthy."

During 2015, the Dollies underwent a series of comprehensive health checks including MRI scans, X-rays and blood tests to check their hearts, blood pressure, joint health and insulin sensitivity. Despite their advanced age, the cloned sheep showed no signs of diabetes, high blood pressure or clinical degenerative-joint disease.

There is still a long way to go before SCNT is perfected. However, this research has shown that cloned animals can live long and healthy lives. Longer term, Sinclair believes that refinements of SCNT could eventually lead to its use in human therapies.

"These improvements will stem from a better understanding of the underlying biology related to the earliest stages of mammalian development. In turn this could lead to the realistic prospect of using SCNT to generate stem cells for therapeutic purposes in humans as well as generating transgenic animals that are healthy, fertile and productive," he said. "However, if these biotechnologies are going to be used in future we need to continue to test their safety."



ABOVE: Dolly's siblings underwent numerous tests and assessments to check their health

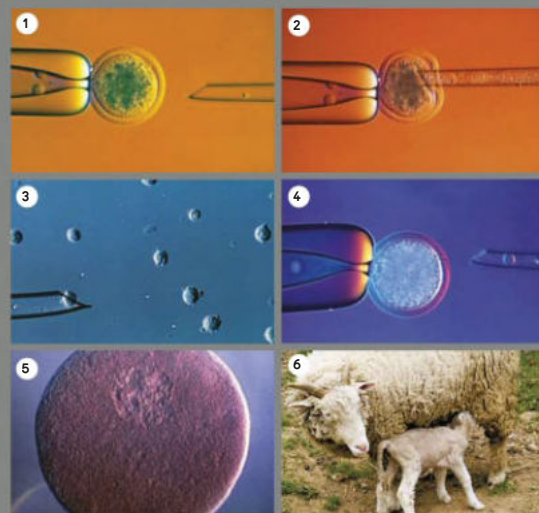
BELOW: X-ray of Debbie the sheep's stifle joint, which is showing signs of osteoarthritis. This is acceptable in a sheep of her age



#### HOW SCNT WORKS

A cell in an early embryo has something akin to a superpower. It can transform into any part of the organism, a skin cell perhaps, a muscle cell, a nerve cell or a blood cell. Before Dolly, everyone assumed that in mammals this process of specialisation, so called 'differentiation', was irreversible. Dolly proved otherwise.

Scientists start with an egg cell **1**. The nucleus (the part of the cell that contains the majority of the genetic material) is removed from the egg cell **2**. A single differentiated cell, in this case an udder cell from an adult donor, is picked up by a tiny needle **3**. The udder cell is injected into the egg cell and a small electrical pulse is used to fuse the nucleus into its new environment and to kick start cell division **4**. The egg cell and differentiated cell fuse. You can see in this image that the egg cell now has a nucleus (upper centre) **5**. The embryo is implanted into the uterus of a surrogate female. She carries the clone to term **6**.





## SPACE

# JUPITER'S GREAT RED SPOT IS HOT STUFF

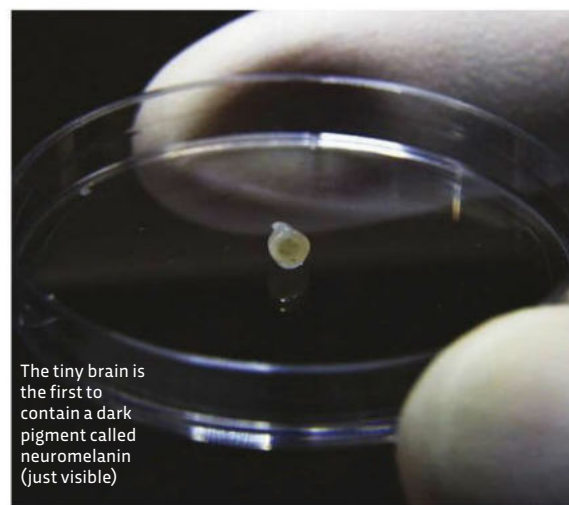
Jupiter's Great Red Spot, a vast raging storm three times the size of Earth, is heating the planet's atmosphere like a giant radiator, researchers from Boston University have found.

When the team measured temperatures across Jupiter's surface by mapping the distribution of the infrared light it emits, they found peaks as high as 1,500°C in the upper atmosphere surrounding the Great Red Spot.

The heating is thought to be due to the action of sound waves and gravity waves produced by the turbulent flows within the storm crashing together like waves on a beach. The finding could explain why gas giants such as Jupiter have upper atmospheric temperatures much higher than would be possible by solar heating alone – something scientists have dubbed an 'energy crisis'.

"With solar heating from above ruled out, we designed observations to map the heat distribution over the entire planet in search for any temperature anomalies that might yield clues as to where the energy is coming from," said lead researcher James O'Donoghue. "The extremely high temperatures observed above the storm appear to be the 'smoking gun' of this energy transfer, indicating that planet-wide heating is a plausible explanation for the 'energy crisis'.

The atmosphere above Jupiter's spot is red hot



The tiny brain is the first to contain a dark pigment called neuromelanin (just visible)

## BIOLOGY

## FUNCTIONING MINI HUMAN BRAINS GROWN IN LAB MAY HELP CURE PARKINSON'S

It may not look like much, but this unassuming blob may help researchers defeat Parkinson's disease and other age-related brain conditions. It's an organoid grown from stem cells to imitate the human midbrain, the 'information superhighway' of the brain that controls hearing, vision, and movement.

Other researchers have successfully grown brain tissue in the lab but the team, made up of researchers from A\*Star Genome Institute of Singapore, the Duke-NUS Medical School and the National Neuroscience Institute, say theirs is the first to contain neuromelanin, a dark pigment found within the human brain that is closely linked to the development of Parkinson's disease.

It also contains specialised neurons that produce dopamine, a neurotransmitter involved with motor control. Low levels of dopamine lead to slowed reactions and disorders like Parkinson's.

"It is remarkable that our midbrain organoids mimic human midbrain development," said researcher Shawn Je. "The cells divide, cluster together in layers, and become electrically and chemically active in three-dimensional environments like our brain. Now we can really test how these mini-brains react to existing or newly developed drugs before treating patients, which will be a game changer for drug development."



Two *Gualicho shinyae*  
on the hunt



## PALAEOLOGY

# MEET A 90-MILLION-YEAR-OLD DINO WITH TINY T. REX ARMS

***Tyrannosaurus rex* had a mini-me!** A dig in Patagonia, Argentina has unearthed a meat-eating dinosaur with a body the size of a polar bear but arms closer in size to those of a human child.

Dubbed *Gualicho shinyae*, the dinosaur is a newly discovered species of bipedal beast belonging to the group known as theropods. It is thought to be closely related to the African dinosaur *Deltadromeus*. Despite this, however, its arms are remarkably similar to those of a *T. rex*, which is a much more distant relative. This suggests that the forelimbs evolved independently on two branches of the evolutionary tree, rather than arising from a common short-armed ancestor.

“IT’S REALLY  
UNUSUAL, IT’S  
DIFFERENT  
FROM THE  
OTHER  
CARNIVOROUS  
DINOSAURS”

“*Gualicho* is kind of a mosaic dinosaur, it has features that you normally see in different kinds of theropods,” said researcher Peter Makovicky. “It’s really unusual, it’s different from the other carnivorous dinosaurs found in the same rock formation, and it doesn’t fit neatly into any category.”

It is not known why some dinosaurs evolved such disproportionately small forearms, but the researchers say finds such as this add to evidence that the unusual trait may have arisen several times independently.

“By learning more about how reduced forelimbs evolved, we may be able to figure out why they evolved,” said Makovicky.



## SPACE

# ASTRONOMERS PRODUCE BIGGEST EVER MAP OF THE UNIVERSE

This might take a while to upload into your sat-nav: a team led by researchers at the University of St Andrews has pieced together a 3D map of the Universe detailing 1.2 million galaxies.

The map is the end product of a decade-long project dubbed the Sloan Digital Sky Survey III (SDSS-III), involving hundreds of scientists from across the globe.

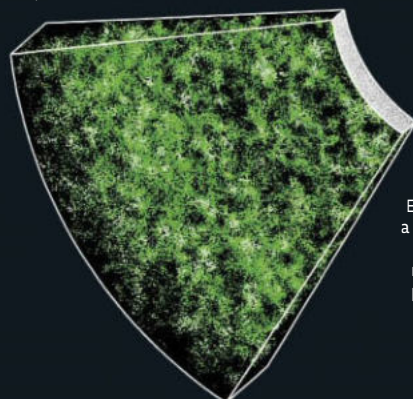
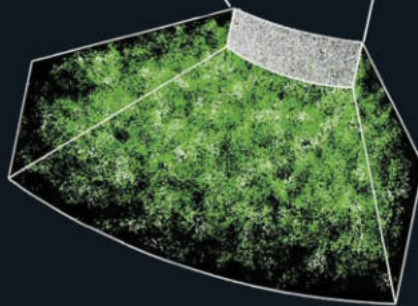
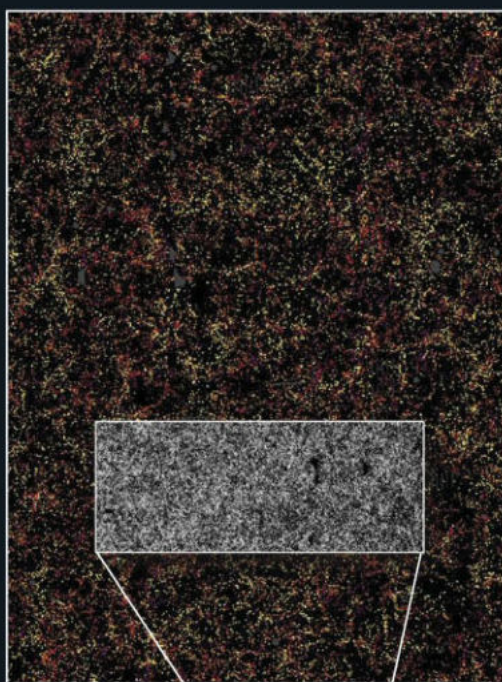
"Over the last decade we have prepared and conducted the largest survey of the Universe yet," said researcher Dr Rita Tojeiro. "By measuring the positions of 1.2 million galaxies over one-quarter of the sky, we mapped the three-dimensional structure of the Universe over a volume of 650 cubic billion light-years."

Researchers hope the vast map will help to further our understanding of the nature of the Universe. It has already been used by the Baryon Oscillation Spectroscopic Survey (BOSS) to make one of the most precise measurements of dark energy – the mysterious force that began pulling the Universe further apart around five billion years ago.

BOSS took extremely sensitive measurements of the expansion of the Universe ranging from seven billion years ago to two billion years ago to investigate the action of dark energy.

"If dark energy has been driving the expansion of the Universe over this time, our map tells us that it is evolving very slowly, if at all: the change is at most 20 per cent over the past seven billion years," said researcher Florian Beutler.

Explore SDSS data for yourself at [sdss.org/dr13/data\\_access](http://sdss.org/dr13/data_access)



Each dot on the top image is a galaxy six billion years into the past; the shaded grey region represents about 10 per cent of the total survey, which has then been transformed into a 3D map

## IN NUMBERS

## 40%

The amount of energy Google has saved thanks to its DeepMind artificial intelligence offshoot. The firm used machine learning algorithms to improve the efficiency of the systems used to cool its vast data centre servers.

## 182.5 cm

The average height of men in the Netherlands, as found by researchers from Imperial College London. This makes them the tallest in the world. Men in the UK came in at 177.5cm. Latvian women were found to be the tallest at 169.8cm, with women in the UK measuring 164.4cm.

## 54°C

The temperature recorded in Mitribah, Kuwait on 21 July, the hottest ever in recent times. The highest on record is 56.7°C, which was measured on 10 July 1913 at Greenland Ranch, Death Valley, California.





Rocky the orangutan has been impressing researchers with his vowel-like vocalisations

ZOOLOGY

# ORANGUTANS RECORDED IMITATING HUMAN CONVERSATIONS FOR THE FIRST TIME

**Step aside King Louie! Here's a great ape with some seriously impressive vocal skills.** An adolescent orangutan named Rocky has been observed imitating the pitch and tone of human vocalisations to produce vowel-like sounds.

The discovery could provide the key to understanding where human language stemmed from, according to the Durham University-based researchers. Previously, it was thought that great apes – the closest living relatives to humans – could not learn to produce new sounds, so speech must have evolved after the evolutionary split between the species.

However, the team found that Rocky was able to imitate a variety of random human vocalisations with variations in the tone or pitch, learn new sounds and control the action of his voice in a 'conversational' context.

---

“ORANGUTANS  
HAVE THE  
POTENTIAL  
CAPACITY TO  
CONTROL THE  
ACTION OF  
THEIR VOICES”

“It's not clear how spoken language evolved from the communication systems of the ancestral great apes. Instead of learning new sounds, it has been presumed that sounds made by great apes are driven by arousal over which they have no control, but our research proves that orangutans have the potential capacity to control the action of their voices,” said researcher Adriano Lameira. “This indicates that the voice control shown by humans could derive from an evolutionary ancestor with similar voice control capacities as those found in orangutans and in all great apes more generally.”

According to the team, the finding opens up the possibility of learning more about the vocal capabilities of common ancestors of orangutans and humans, and could shed light on how full-blown speech evolved in humans.

PHOTOS: MARK KASER



## PHYSICS

# WIMPING OUT TIME

After almost two years of searching, scientists at South Dakota's Large Underground Xenon (LUX) detector remain in the dark over the nature of dark matter.

Around 85 per cent of the mass in the Universe is thought to consist of dark matter. But as it doesn't emit light and pretty much only interacts with other matter via gravity, it is incredibly difficult to detect.

The LUX experiment was set up to search for WIMPs, or 'weakly interacting massive particles'. These are one of the leading theoretical candidates for dark matter that, as their name suggests, have a small mass and interact with other matter via the weak nuclear force. If they exist, billions of WIMPs should pass through the Earth every second. However, after 20 months of operation LUX has failed to find a single one.

"We've probed previously unexplored regions of space with the aim of making the first definitive discovery of dark matter. Though a positive signal would have been welcome, nature was not so kind!" said LUX collaborator Dr Cham Ghag of University College London. "Nonetheless, a null result is significant as it changes the landscape of the field by constraining models for what dark matter could be beyond anything that existed previously."

In the coming months, scientists will continue to analyse the data that LUX was able to provide, in hope of helping future experiments to pin down a dark matter particle.

Longer term, the team is now working on the LUX-ZEPLIN (LZ) experiment, a detector planned to be over 70 times more sensitive than LUX.

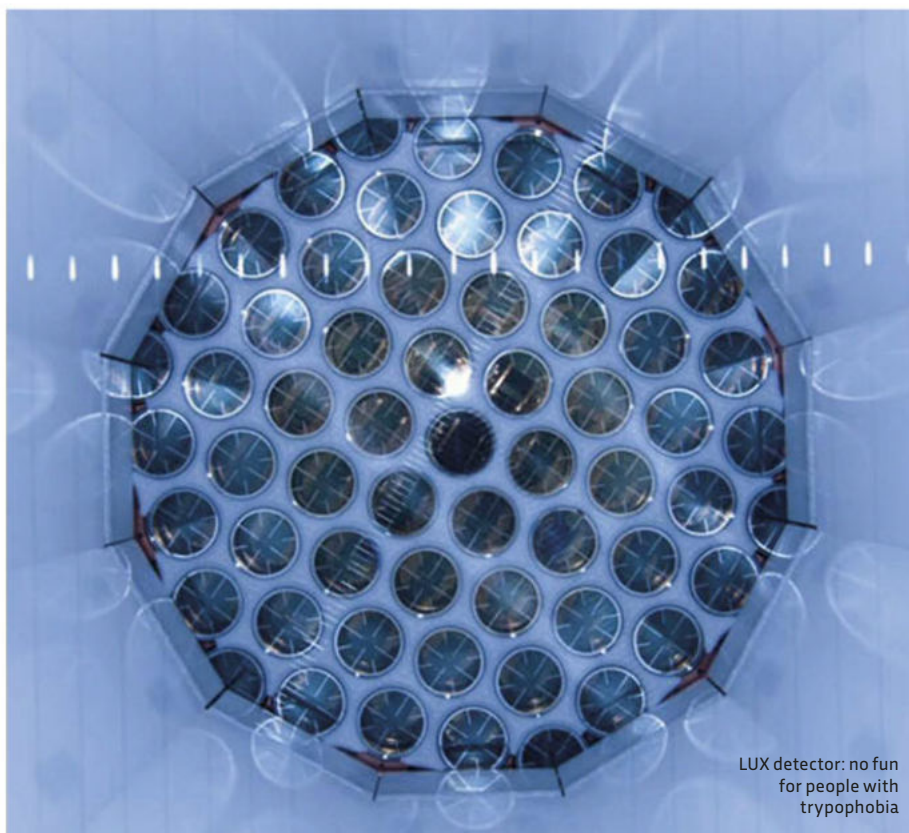


PHOTO: C.H. FAHAM ILLUSTRATION: RAJA LOCKEY

LUX detector: no fun for people with trypophobia

## THEY DID WHAT?!



## Researchers eavesdrop on pigs' grunts

### What did they do?

A team from Queens University, Belfast kept pigs in two different pens: one small and bare with a concrete floor, and one large and filled with soft straw bedding. One-by-one they led the pigs out of the pens, kept them in isolation for three minutes before moving them into a pen where they could investigate an object they had not encountered before.

### Why did they do that?

Pigs are extremely social animals who communicate via grunts. The team wanted to see if the pigs' differing personalities affected their style of grunting.

### What did they find?

The pigs with more inquisitive personalities were found to grunt more frequently while pigs kept in the poorer conditions were found to be quieter. The results suggest that pigs' grunts contain important information about their personalities, psychological state and welfare, the researchers say.



## PALAEOLOGY

# THINK YOU KNOW WHY TURTLES HAVE SHELLS? THINK AGAIN.



The proto turtle fossil was partially shelled (left). The ribs eventually became incorporated into the shell, as seen in modern turtles (right)

“JUST LIKE THE BIRD FEATHER DID NOT INITIALLY EVOLVE FOR FLIGHT, THE EARLIEST BEGINNINGS OF THE TURTLE SHELL WAS NOT FOR PROTECTION BUT RATHER FOR DIGGING UNDERGROUND”

They may serve as natty personal caravans or protective carapaces, but new evidence suggests turtles' shells originally evolved to help the animals burrow underground.

Key to the discovery was a 260 million-year-old fossil of a partially shelled ‘proto turtle’ found by eight-year-old Kobus Snyman, who took the fossil to a local museum after finding it on his father's farm in the Western Cape of South Africa.

“Why the turtle shell evolved is a very Dr Seuss-like question and the answer seems pretty obvious – it was for protection,” said lead author of the study Dr Tyler Lyson. “But just like the bird feather did not initially evolve for flight, the earliest beginnings of the turtle shell was not for protection but rather for digging underground to escape the harsh South African environment where these early proto turtles lived.”

The previous fossil record showed that turtles ancestors' ribs began to broaden, eventually forming the framework to hold the shell. This had long puzzled scientists as broadened ribs would make the animal's torso stiffer, which in turn would shorten its stride, slow it down and interfere with its breathing – all of which would add up to it being a sitting duck for predators.

“The integral role of ribs in both locomotion and breathing is likely why we don't see much variation in the shape of ribs,” said Lyson. “Ribs are generally pretty boring bones. The ribs of whales, snakes, dinosaurs, humans, and pretty much all other animals look the same. Turtles are the one exception, where they are highly modified to form the majority of the shell.”

However, from studying the fossil, researchers have deduced that wider ribs would have given the animal a stable base for its powerful forelimbs to dig from, enabling it to burrow more effectively.





## THE DOWNLOAD

## LUCA

**Oooh, what's that? A new Italian restaurant chain?**

Nope. It's the 'last universal common ancestor', essentially the granddaddy of all life on Earth.

**Cool. What exactly is it?**

We can't be sure, as it didn't leave any fossils behind. But all evidence points to it being some kind of single-celled organism.

**Hang on. If we don't know what it is, why are we talking about it?**

Well, a team at the University of Düsseldorf has combed through more than six million genes in samples of bacteria and archaea, the two oldest forms of life, to tease out 355 genes that they think originated in LUCA.

**So, have they figured out exactly what LUCA was?**

Yep, they think it was similar to the thermophiles that still exist today. These organisms live around the mineral-rich thermal vents deep in the sea.



LUCA could be similar to thermophiles like this

## HUMANS

## EARLIEST HUMAN CANCER FOUND IN 1.7 MILLION-YEAR-OLD FOOT BONE

Cancer may not be such a modern malady after all. Researchers from the University of the Witwatersrand, Johannesburg, have discovered some of the most ancient evidence for cancer ever found in the human fossil record.

The cancer was found in a foot bone belonging to an unknown species of hominin, or bipedal human relative, that walked the Earth around 1.7 million years ago in Swartkrans, a national heritage site found about 30km from Johannesburg in South Africa. For comparison, modern humans are only about 200,000 years old.

"Modern medicine tends to assume that cancers and tumours in humans are diseases caused by modern lifestyles and environments," said researcher Edward Odes. "Our studies show the origins of these diseases occurred in our ancient relatives millions of years before modern industrial societies existed."

The cancer was found in a metatarsal, a bone located in the middle of the foot, using state-of-the-art CT imaging technologies. It was identified as an osteosarcoma, an aggressive form of cancer that usually affects younger individuals in modern humans. If untreated, it typically results in early death.

"Due to its preservation, we don't know whether the single cancerous foot bone belongs to an adult or child, nor whether the cancer caused the death of this individual, but we can tell this would have affected the individuals' ability to walk or run," said researcher Bernhard Zipfel. "In short, it would have been painful."



In this image, the extent of the cancer can be clearly seen at the top left of the foot bone



## ASTROBIOLOGY

"The capability to produce medicine is going to be important for long-term, deep space travel"

*The Chernobyl disaster caused some local fungi to become resistant to radiation. The University of Southern California (USC) and NASA have now sent those strains into space. We talk to USC's Prof Clay Wang*

**On 18 July, SpaceX launched the CRS-9 mission. Its Dragon capsule carried fungi to the International Space Station (ISS). So why are you sending microbes into space?**

Microorganisms such as fungi have been used as a source of medicine for years. Penicillin is a great example of a secondary metabolite [a compound not directly involved with the growth of the organism] that is made by a fungus. Our research has shown that when you look at the genome of these microorganisms, they can actually produce

many more secondary metabolites, but only in stressful conditions.

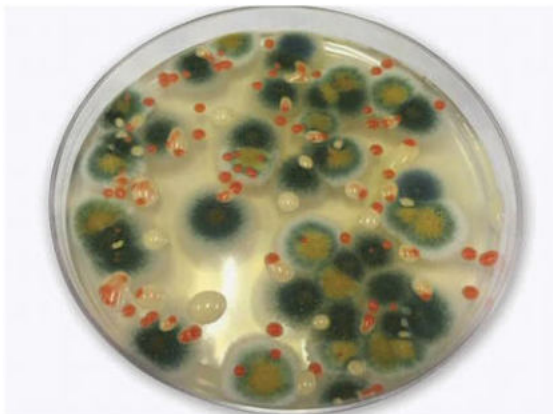
We're really interested in the conditions on the ISS, where there's microgravity and radiation. We also want to see whether we can trigger the production of other metabolites so we can test whether they're going to be useful substances.

**What's so special about these strains?**

After the Chernobyl accident, there was an 'exclusion zone' put in place around the site of the disaster. For this launch, we sent eight different fungi from the Chernobyl site. Two of them display 'radiotropism', which means they grow toward radiation. They're probably using radiation as a source of energy. Then we also have six different organisms that have the potential to make various molecules that could be useful for agriculture and medicine. For example there's *Aspergillus terreus*, the producer of lovastatin, which is a well-known cholesterol-lowering drug.

**Doesn't radiation normally damage DNA?**

Yeah, it kills. So does it mean there's a special process here? One of the key things we would like study is genes related to DNA damage-repair.



RIGHT: Some microbes can naturally occur on the ISS. Microbial Tracking Observatory-1 is an ongoing experiment that involves taking samples from the ISS to see what's growing there

PHOTOS: GETTY, NASA





ABOVE: Microbes will be exposed to stressful conditions at the ISS (pictured) to try and trigger the production of secondary metabolites, which could have medical uses

### Why don't you grow the organisms in artificial stress conditions in a lab?

One of NASA's main missions now is for long-term space travel. It's going to take a couple of years to get to Mars and back, for example. Right now we're on the ISS, which is still in Earth's orbit. We can deliver items and if astronauts don't use them, they get thrown away or we can replace them easily. But on a long-term mission, that's not going to be possible. A lot of medical compounds have expiration dates, so the ability to produce medicine using microbes is going to be important for long-term, deep space travel.

### The fungi return to Earth in September. When will you start studying them?

The splashdown of the Dragon capsule will be outside Los Angeles, in the Pacific Ocean. We get an update directly from NASA when a capsule leaves the ISS. Within 24 hours, it gets delivered to Long Beach harbour then the Long Beach airport, where a NASA transporter sends it back to the Houston headquarters. As we're located in Los Angeles, we collect the samples from Long Beach airport and then bring them back to our lab, so we can start analysing them the next day.



## THUMBSUCKERS

Perhaps your mum shouldn't have shouted at you for sucking your thumb or biting your nails. Those guilty of these bad habits when growing up could be less likely to develop allergic sensitivities in later life, researchers in New Zealand have found.

## HEAVY METALLERS

If you prefer moshing to Motörhead to relaxing to Rachmaninoff, read on. Dutch and German researchers found that fans of the often death-themed music develop a 'buffer' that makes them less stressed when contemplating their inevitable departure from the living realm.

## GOOD MONTH

## BAD MONTH

## ONLINE BRAGGING

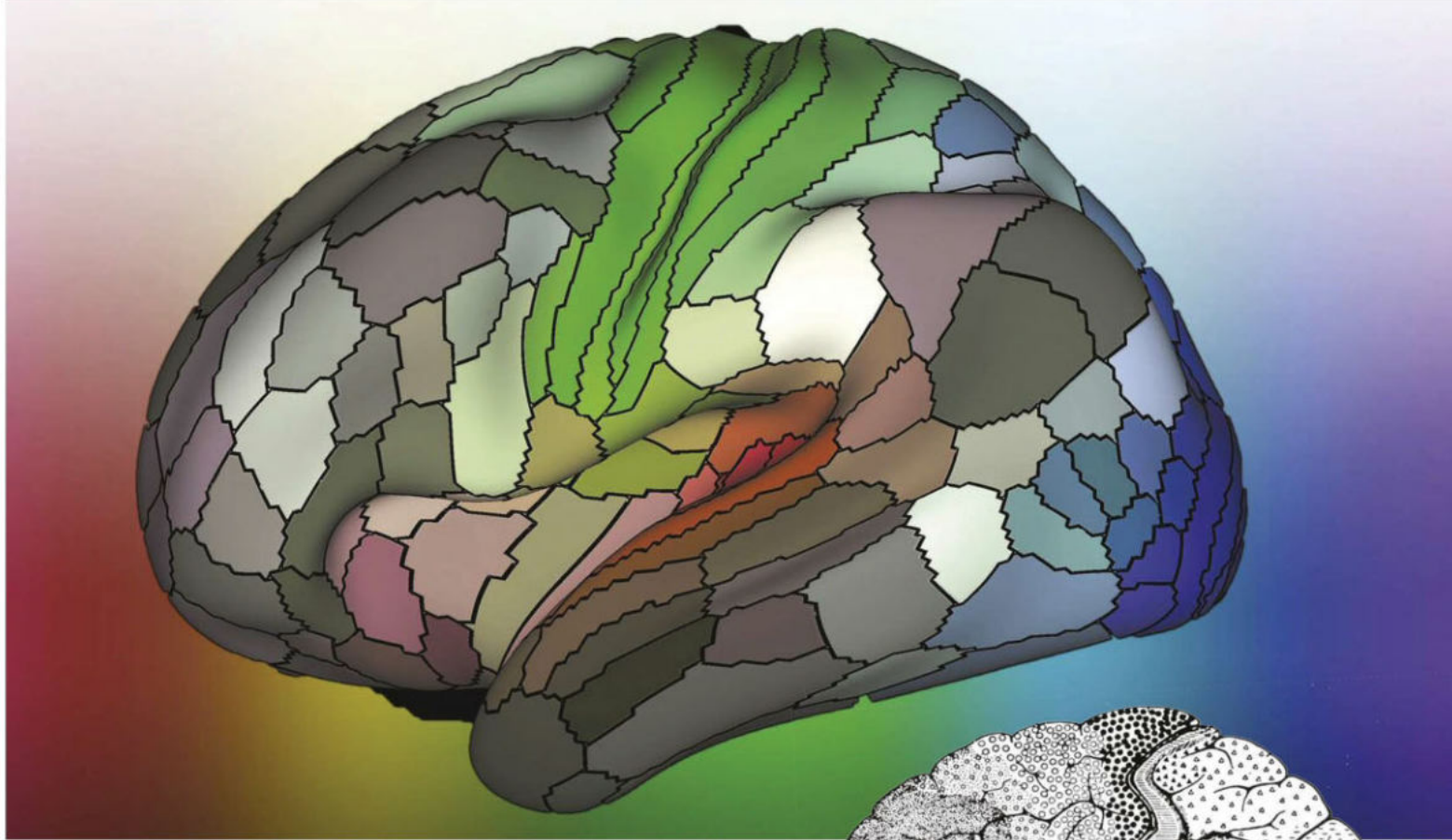
Does your Tinder profile list your qualifications, bicep size and salary? If so, rewrite it. Those in the dating game who boast too much are seen as less attractive than their more modest counterparts, according to a University of Iowa study.

## COMEDIANS

Death is no laughing matter. A team at the Australian Catholic University has found that stand-ups die younger than other entertainers, with those regarded as funnier popping their clogs even sooner.







## NEUROSCIENCE

# SCIENTISTS COMPLETE DETAILED MAP OF CORTEX

**This really is a mind map:** researchers from Washington University have produced the most accurate picture of the human cerebral cortex to date, dividing it into 180 distinct regions.

The cortex is a layer of neural tissue that shrouds the rest of the brain like a crumpled sheet of paper. It is involved in many processes including sensation, attention, memory, perception, thought, language and consciousness.

"The brain is not like a computer that can support any operating system and run any software," said co-lead researcher Dr David Van Essen. "Instead, the software – how the brain works – is intimately correlated with the brain's structure – its hardware – so to speak. If you want to find out what the brain can do, you have to understand how it is organised and wired."

The cortex of the human brain was first mapped by the German neuroscientist Korbinian Brodmann more than 100 years ago. He identified 50 distinct regions of the cortex, but as technology and knowledge progressed it became

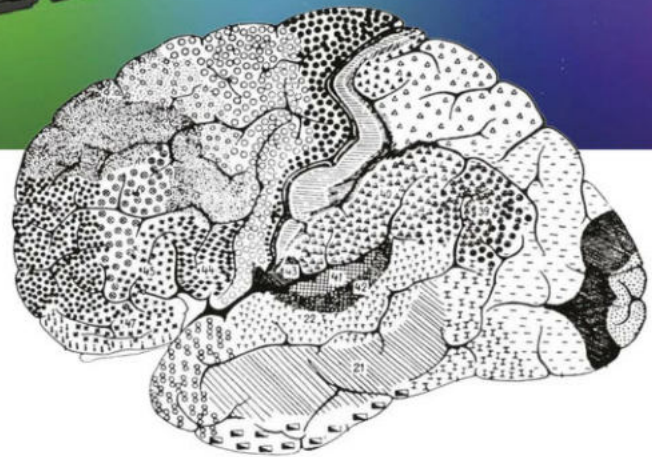
clear that his map was in serious need of an update.

"My early work on language connectivity involved taking that 100-year-old map and trying to guess where Brodmann's areas were in relation to the pathways underneath them," said co-lead researcher Dr Matthew Glasser. "It quickly became obvious to me that we needed a better way to map the areas in the living brains that we were studying."

The team pieced together their new map from a number of MRI scans taken from 210 healthy adults, some of the resting brain and some of the brain performing simple tasks like reading a story.

They found that some areas are clearly involved in particular actions, such as vision or controlling movement, but most coordinate information from many different signals.

According to the researchers, scientists will now be able to use the map to help them understand differences in the brains of patients with diseases such as schizophrenia, dementia and epilepsy, compared with adults who are healthy.



TOP: The new map of the cerebral cortex, created by the team at Washington University

ABOVE: Korbinian Brodmann's map of the cortex, which he drew up over 100 years ago

## HEALTH

## NASAL BACTERIA TURN THE HUMAN NOSE INTO AN ANTIBIOTIC FACTORY

Sometimes you can spend hours looking for something only to find it was in front of your nose all along. This is certainly the case for a group of researchers from Germany's University of Tübingen who have found a potent antibiotic created by bacteria that inhabit the human nose.

The team found that *Staphylococcus lugdunensis* bacteria present in the human nasal cavity are capable of producing lugdunin, a powerful antibiotic with a previously undiscovered chemical structure.

The findings open up the possibility of finding other new and useful antibiotics in the human body.

"Normally antibiotics are formed only by soil bacteria and fungi," said study co-author Prof Andreas Peschel. "The notion that human

microflora may also be a source of antimicrobial agents is a new discovery."

Tests on mice have shown that lugdunin can be used to combat pathogens that have become resistant to many traditional antibiotics, potentially making it an effective tool to fight the growing problem of antibiotic resistance.

"There are estimates which suggests that more people will die from resistant bacteria in the coming decades than cancer," said study co-author Bernhard Krismer. "The improper use of antibiotics strengthens this alarming development."

One potential use would be to introduce the otherwise harmless lugdunin-forming bacteria to patients at risk from MRSA as a preventative measure, the researchers say.

BELOW: Researchers can grow bacteria in the lab to test antibiotics

## WHAT WE LEARNED THIS MONTH

### WHALES MOURN THEIR DEAD

Researchers from Italy have observed six species of whales clinging to the bodies of a dead podmate, in clear pain and distress. The findings mean whales join chimps, giraffes and elephants in displaying signs of grief.

### IT'S TIME TO SAY GOODBYE TO THE PHILAE LANDER

After more than a year of failed attempts, ESA have given up trying to contact Philae – the part of the Rosetta mission that landed on the distant comet 67P. Farewell, plucky little spacecraft.

### BABY TALK HELPS CHILDREN LEARN TO SPEAK

Coochy cool! Speaking 'motherese' to your little 'un may help them pick up languages more quickly. The effect is due to the exaggeration of certain sounds, making them easier for babies to pick up.

### APOLLO ASTRONAUTS ARE FIVE TIMES MORE LIKELY TO DIE FROM HEART DISEASE

The effect is thought to be due to exposure to dangerous cosmic radiation that comes from travelling outside of the Earth's protective magnetic field.





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# INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

SEPTEMBER 2016

EDITED BY RUSSELL DEEKS



## ATTACK OF THE DRONES

*Official Star Wars drones to land just in time for Christmas...*

These are the drones you're looking for. Later this year, the first official *Star Wars* drones, made by Propel, go on sale. There's a speeder bike (pictured), an X-wing, a TIE Fighter and the Millennium Falcon. While they won't make the Kessel Run in under 12 parsecs (and this is actually a unit of distance, not time), they do have a 'battle mode' which lets pilots play aerial laser tag. Christmas sorted.



# MIGHTY MORPHER



With the push of a button, the rig can increase its length by 122cm and its width by 25cm

The outer shell is added in post-production using CGI. We'd like a spotty pink one, please



See this strange-looking vehicle? It's not just any car – it's every car!

Built by UK design and special effects agency The Mill and custom vehicle fabricators JemFX, the Blackbird is

designed to remove the need for movie-makers to source high-end or vintage vehicles for use in their films.

Instead, they can now simply call on the services of the Blackbird, whose chassis can be adjusted to match the length and width of any vehicle, and

## BLACKBIRD'S CHASSIS CAN BE ADJUSTED TO MATCH THE LENGTH AND WIDTH OF ANY VEHICLE

Blackbird rig, with the relevant vehicle's outer shell added in post-production using CGI.

The rig also incorporates cameras and sensors to enable the creation of 'car's-eye view' sequences, whether in film or in virtual reality.

whose electric engine can be programmed to match the car in question's acceleration, braking, corner-handling and so on. Car chases and such can then be filmed using the bare

### NEWS BYTES



#### TAKEAWAY BOTS HIT UK

Remember the Australian pizza-delivery robot we told you about a few issues ago? Well, a similar service is now available in the UK. Developed by Starship Technologies, the robots are currently undergoing real-world testing in London by the Just Eat takeaway network.

#### AI PARKING PAL

An AI chatbot created by a British student at Stanford University has successfully contested over 160,000 parking tickets in New York and London, saving drivers over \$4m in fines. If you've had a ticket you're not happy about, visit [donotpay.co.uk](https://donotpay.co.uk) to use the service for yourself.

#### SHEEP VIEW

Google StreetView is great, but its coverage isn't ubiquitous. It doesn't cover the remote Faroe Islands, for instance. Enterprising locals have therefore created their own version, by attaching 360° cameras to the collars of some of the island's 80,000 sheep.

#### FASTEST-EVER SUPERCOMPUTER

IBM has announced that it expects to have a 200-petaflop supercomputer ready for use by the US Dept of Energy by 2018. Assuming all goes well, that will make it the fastest supercomputer in the world.

#### HUBBLE'S LIFE EXTENDED

Few pieces of space tech have captured the public imagination like the Hubble Space Telescope. So we're delighted to hear that Hubble's operational life has been extended by three years. It will now continue operations until at least 2021 – three years after the launch of its replacement, the James Webb Space Telescope.



## ROBOTS

Cuter than a cat, and more useful too!

## Clever little Cozmo

Robot toys are getting smarter all the time, but Cozmo, the brainchild of toy developers Anki, could be the smartest yet. It will be coming to the US and UK market later this year.

Until now, Anki has been best known for its smartphone-controlled toy racing cars. But Anki co-founder Hanns Tappeiner has an extensive background in robotics and machine learning. He and his team have drawn on that knowledge to create the palm-sized Cozmo. While the robot can do much the same sort of things as other robot toys – play games, respond to voice commands and so on – what's really

special is that it will ship with Python-based programming apps. This will let inexperienced users customise its behaviour and teach it new tricks.

It also has a range of 'emotional' responses of its own, created by a team of former Pixar animators. If you beat it at a game, for instance, don't be surprised if it goes into a sulk.

Just as the ZX Spectrum and Commodore 64 computers introduced a new generation of youngsters to programming in the 80s, Anki hopes that Cozmo will go on to inspire the next wave of roboticists, programmers and AI specialists.

## SECURITY

## Goodbye Tor, hello Riffle?

Researchers at Massachusetts Institute of Technology (MIT) in the US have developed a new secure communications protocol called Riffle that's said to be even more impregnable than Tor, the system that currently underpins the 'dark web'.

Tor, 'the onion router', works by wrapping all communications in multiple layers of encryption, then routing the information through multiple relays. But as recent FBI operations have demonstrated, Tor isn't truly impermeable: if spies or hackers can take control of enough 'nodes' (relays) on the network, they can identify which traffic is going to and from any individual user.



## TRANSPORT

## Hyperloop: not just for Californians

When Elon Musk's SpaceX first proposed its high-speed Hyperloop system, which would send passengers and cargo through tubes using compressed air, the idea was to reduce journey times between Los Angeles and San Francisco. Now, though, it looks like the technology may be coming to Russia.

Hyperloop One – the SpaceX offshoot which is developing the technology – has already signed a deal with Russia's Summa Group to explore the possibility of building such a network to link the cities of Moscow and St Petersburg, and eventually Moscow with Siberia. And now, a feasibility study conducted by Hyperloop One and accountancy firm KPMG suggests that a similar system could even be built below the Baltic Sea, reducing journey times from Helsinki to Stockholm from over three hours to just 28 minutes.



Testing the Hyperloop in the Nevada desert



# WANTED!

## FURBY'S BACK!

### FURBY CONNECT

Remember Furby, the fuzzy robot toy that caused such a fuss around the turn of the millennium? Well, Hasbro's making one of its periodic bids to reboot the brand, and this latest version of the gremlin-like electronic pet now connects via Bluetooth to a smartphone/tablet app so kids can play games and watch Furby videos. It now boasts a vocabulary of over 1,000 phrases – and, mercifully, comes with a sleep mask so you can turn it off.

£99.99, [furbys.com](http://furbys.com)



## MEASURE UP

### BAGEL

This new measuring device offers a choice of three modes. String works like a normal tape measure but with a digital read-out, Wheel lets you measure irregularly shaped objects by simply rolling Bagel across them and Remote is a laser measure with a range of 5m. Throw in a smartphone app to record measurements and a voice recorder so you can remember what's what, and Bagel is surely a must-have for any self-respecting gadget lover's toolbox.

\$85 (£65 approx), [bagel-labs.com](http://bagel-labs.com)

## MOVIE MAKER

### YOCAM

YoCam takes the ultra-portability that made the Flip Mino HD such a huge success half a decade ago, and adds a host of features to make it more versatile. There's Wi-Fi and Bluetooth, P2P connectivity so you can use it as a security cam, built-in video editing and social sharing capabilities, a 140° wide-angle lens, MoSteady image stabilisation and, of course, it's waterproof to six metres.

\$200 (£150 approx), [getyocam.com](http://getyocam.com)



## MUSIC BOX

COMO AUDIO DUETTO

Soup  
up your  
sounds



Offering Wi-Fi, NFC and Bluetooth connectivity, plus aux, optical and USB inputs, this all-in-one internet/DAB/FM radio and streaming audio player has quite a pedigree behind it, having been designed by the man who set up Cambridge Soundworks

and Tivoli Audio. It is multi-room capable, has a built-in Class D amp pumping out 30W per channel through 19mm tweeters and three-inch woofers, and can be controlled via an optional iOS or Android app.

**From \$319 (£240 approx), [comoaudio.com](http://comoaudio.com)**

## NOW HERE THIS

DOPPLER LABS HERE ONE

New from audio innovators Doppler Labs come these wireless in-ear buds that function as earphones, customisable earplugs and a smartphone accessory all at once. The first time you put the Here Ones in your ears you can tweak their frequency response to your individual hearing, while multiple built-in directional mics enable you to 'tune out' specific sounds. The buds can stream music but also work with digital assistants like Siri and Google Now, and you can even apply digital effects like reverb and flanging.

**\$299 (£230 approx), [hereplus.me](http://hereplus.me)**

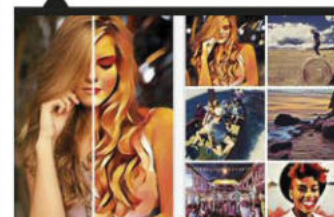


### APP FEED



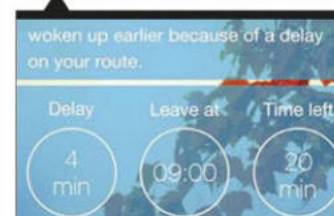
#### Prisma

This set of 34 filters uses neural networks to turn any photo on your phone or tablet into a masterpiece in the style of Van Gogh, Mondrian or Monet. *Free, iOS/Android*



#### Snorelax

Imagine an alarm clock app that monitored traffic reports, and woke you a bit earlier if there was a jam on your route. Actually, you don't have to imagine any more... *£1.49, iOS*



#### BBC iPlayer Radio

The iPlayer radio app is now available internationally, meaning over 60 million listeners around the globe can now catch up with their fave shows on their mobile devices. *Free, iOS/Android*





# MAKING WAVES

Your phone might be smart, but how good is it at reproducing music? The Hugo is a genius way to get studio-quality audio from any device and perfect your listening experience

**T**wenty years ago, if you'd told music fans they'd one day be able to carry their entire record collection in their pocket, you'd have been laughed out of the room. If you'd gone on to add that they'd also be able to access nearly every song ever recorded at the touch of a button, wherever they were, you'd have been met with concerned looks and some sage advice to maybe lay off the drink.

Yet that's exactly what's happened. The convergence in development of a few different technologies – smaller microprocessors, digital encoding and high-speed internet – has ushered in a golden age for music lovers. Music has never been easier to access. But portability and accessibility has come at a cost: quality.

## LOW FIDELITY

You see, reproducing audio is a complicated business. Over the past few decades we've experimented with a few different methods, which you can read about on the opposite page. But these days, convenience means most of us get our musical fix from digital formats.

At a basic level, a digital audio file is a string of binary code, a lengthy series of ones and zeros that represents all the audio information that makes up a song. To reproduce the recording, a chip in your laptop or phone called a digital to analogue converter (DAC) reads the code and generates an electrical signal. When that signal reaches a loudspeaker, you hear sound.

Unfortunately, using a good quality DAC isn't a priority for most electronics manufacturers. Developing the code and circuitry needed is time-consuming and expensive, so typically smartphones and computers ship with a budget option. That means their audio output is stripped of a lot of information, resulting in an end product that sounds a long way from what the artist intended. But there is a solution.

The Hugo is an external DAC created by the audio engineers at Chord Electronics. It's a seriously high-end bit of kit, engineered using techniques developed over 25 years of working with some of the world's leading broadcasters, recording studios and film stages. Chord's proprietary technology doesn't add or remove anything from the original recording; instead, it provides a window onto the original, letting you hear it exactly as the artist intended. The difference is astonishing.

The Hugo is designed to be versatile. It's highly portable and robust, and a single charge lasts 10 hours, so it's ideal for listening on the go, but also has the power to improve even the most high-end hi-fi. It's found its way into professional audio setups around the world, where its ability to accurately reproduce waveforms is vital in mixing and mastering. There's also a desktop version, the Hugo TT, for home use.

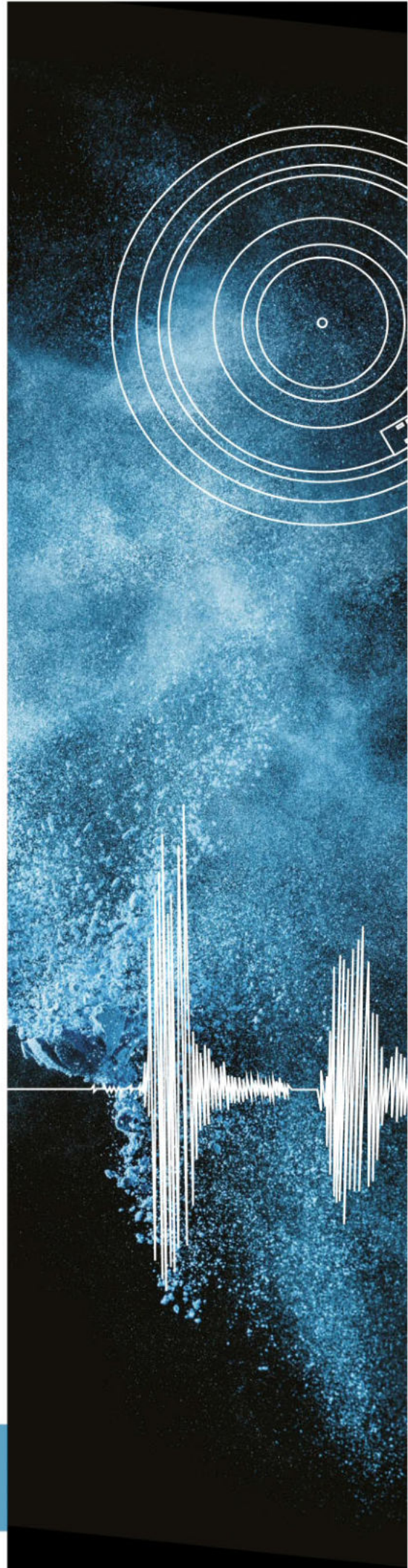
If you'd like to hear the difference a Hugo can make, you can enter the competition opposite. In the meantime, let Chord Electronics give you the lowdown on how audio reproduction has developed over the last few decades.



**WHAT HI-FI?  
AWARDS 2014**

**DACs**  
Best DAC £1000+  
**Chord Hugo**

Find out more about the Hugo's groundbreaking technology at [chordelectronics.co.uk/chord-hugo.asp](http://chordelectronics.co.uk/chord-hugo.asp)







## VINYL

Unlike modern audio reproduction, vinyl records store sound in a mechanical way. That means there's a direct physical relationship between the audio and the record itself. During the pressing process, recorded soundwaves are physically carved into the record's plastic surface by a stylus. This emulates the peaks and troughs of any given soundwave; when a different kind of stylus runs down the grooves it vibrates in the exact same way. The stylus is connected to an electromagnetic device called a cartridge, which converts the vibrations to electrical signal, then to an amp, which increases their energy. A loudspeaker converts this electrical signal to soundwaves.



## CD

CDs are made from a thin layer of aluminium sandwiched in polycarbonate, with a protective layer of lacquer. Unlike tape and vinyl, music is stored digitally on a CD, as a string of numbers. That's done through a process called sampling, in which audio is 'listened to' 44,100 times a second by a piece of software which converts each sample to binary code. The result is written to the aluminium layer using a laser, where a burn represents a zero, and an unburnt area represents a one. When a laser reads these marks it understands whether it's looking at a one or a zero, by the way the light reflects – a zero will reflect smoothly, while a one will cause it to scatter. A DAC converts the binary readings to an electrical signal, which is converted to sound by a loudspeaker.



## WAV

WAV encoding was developed in 1991, so it predates the widespread adoption of MP3s by about 10 years. But they're actually a far more accurate reproduction. To understand why, you need to know how MP3s work. Both formats convert audio to binary using the same 44.1kHz sampling as CDs, but MP3s are designed to be as small as possible. They do that by using the principles of psychoacoustics – the study of how we perceive sound – to remove information the human ear isn't consciously aware of. For example, there are certain frequencies humans can't hear, so they're removed. Equally, if we hear a loud sound and a quiet sound together our brain ignores the quiet sound – so the MP3 encoder takes it out. There are some advantages to this: MP3s take up much less memory, and they provide a reasonably accurate reproduction. But all that extra information means that WAVs, like vinyl and CDs, have an indefinable richness to their sound that MP3s can't provide.

**WIN A HUGO  
DAC WORTH  
£1400**

Fancy winning your own piece of Chord Electronic's award-winning technology? Head to [bit.ly/HugoComp](http://bit.ly/HugoComp) and answer a simple question to be in with a chance of bagging this prize.



# REPLY

*Your opinions on science, technology and BBC Focus*

## MESSAGE OF THE MONTH

### Dirty dancing

After reading your article by James Witts about professional vs casual cycling gear (July, p88), I was intrigued by the use of bicarbonate of soda as a fatigue buster. I am a dancer in training, so naturally the idea of getting through an intense exercise session with less lactic acid build-up appealed to me.

Though the teaspoon or so I consumed appeared at first to have the desired effect, it also had another, less pleasant one. Halfway through my class, I experienced what can only be described as the worst case of the runs I've ever had. I thought I had food poisoning! My advice to anyone wanting to try this is to do it at home BEFORE using it to boost training. That way any nasty side effects can be dealt with in private!

Isla Hurst, via email

➔ Hi Isla, I'm sorry to say you were one of the unfortunate few. Sodium bicarbonate has been known to deliver the occasional unwanted side effect. So apologies are in order, I should have stressed that you should try first within short distance of a toilet!

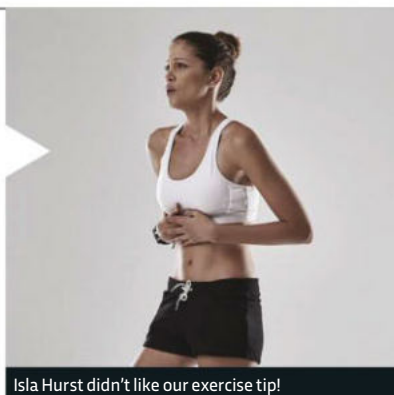
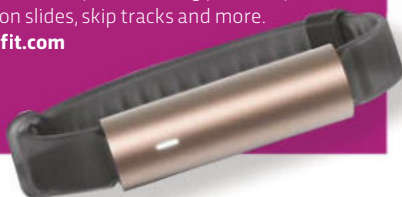
Nonetheless, the benefits of the technique are proven and published in a number of journals, and has even been documented in animals! Take the case of Australian horse trainers, who were accused of 'doping' the animals with bicarbonate of soda back in 2011. One trainer had used this technique for years and said it gave his equine minions a significant performance boost. Possibly one time when you're after rapid trots!

– James Witts, science writer and author of *The Science Of The Tour De France*

### WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a Misfit Ray tracker. As well as tracking your sleep and activity, the Ray controls your smartphone, letting you take pictures, control presentation slides, skip tracks and more. Check it out at [misfit.com](http://misfit.com)

WORTH  
£80



Isla Hurst didn't like our exercise tip!

### We're listening

The article about the robot that pretends to care (July, p31) may seem like a pointless achievement to some but I disagree. If applied correctly, these little CommU bots could help make our world a far less stressful environment. There are a lot of people who would like someone or something to listen to them. Not to understand, just to listen! With the pace at which people live today, few have the time nor the inclination to listen.

M Stokes, via email

### Heart to heart

The Michael Reiss article on xenotransplantation was informative (August, p67). Yet I suspect I was not the only reader who found it disturbing. As far as possible, we need to allow each species to live a life that their nature intends, otherwise they suffer. Keeping a pig in a sterile chamber falls into this category.

Future populations will not necessarily despise our current convictions of using animals for food and research, but surely any practice that proliferates the suffering of animals will be considered barbaric.

David Fitzgerald, Margate

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## MORE FOCUS FOR YOU

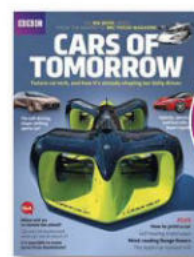
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Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied. [sciencefocus.com](http://sciencefocus.com)



## Special issue



ON  
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### CARS OF TOMORROW

Supercharge your knowledge of the cars of the future with our latest special edition. It includes a buyer's guide to different fuel types, expert Q&As, the hottest car-based technology, and more.





MUON  
JUST GOT  
MIGHTY  
SMALL



*"If the KEF MUO was to walk into a roomful of Bluetooth speakers, there's no doubt a respectful hush would descend: it's royalty when it comes to audio quality."*

Alphr, February 2016

## Muo WIRELESS SPEAKER

Design by Ross Lovegrove. Sound by KEF.

Innovation disrupts. When KEF collaborated with design guru Ross Lovegrove to create the mighty MUON, it rocked the world of extreme high end audio. Inspired by the mighty MUON's sculptural organic form and breakthrough technologies, the MUO makes new waves in the pursuit of art and sound perfection.

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ILLUSTRATION: ANDY POTTS





★★★★★

# ARE YOU A **GENETIC SUPERHERO?**

Recent research has revealed a handful of 'superheroes' walking among us, whose DNA gifts them with resistance against serious diseases. Now we just have to find them...

Words: **Kat Arney**





uperheroes are everywhere right now. Righting wrongs, saving planets and generally

punching each other senseless in films, comic books and TV shows. But just as Clark Kent wanders unrecognised through the world, only turning into Superman when his help is needed, there are genetic superheroes dwelling among us, and in most cases they're completely unaware of their amazing powers. Only now, by trawling through the DNA of thousands of people, are we discovering their hidden identities.

#### FAULTY GENES

Dr Cisca Wijmenga and her team at the University of Groningen in the Netherlands never set out to find superheroes. Their project was important but unexciting: reading the DNA of 250 Dutch families to establish a baseline for the genetic make-up of the country. Then, as future studies



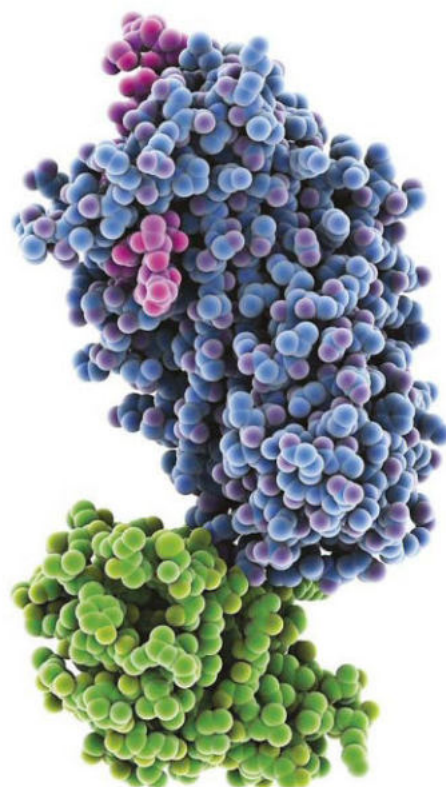
*There are hundreds of healthy Dutch people going about their daily lives, defying the faulty genes within them*

turned up interesting gene variations and faults (mutations) linked to disease, they would be able to tell if they were genuinely responsible for causing illness or just part of the underlying DNA of Dutchness.

Then they found them. Two unlikely heroes, both in their sixties and both carrying two faulty copies of a gene called SERPIN A1 (we usually have two copies of every gene, one from mum and the other from dad). This particular gene normally

makes a protein that helps to protect the tubes and air sacs in the lungs. Without it, these delicate structures start to break down, causing serious breathing problems by 30 to 40 years of age. But these two individuals had both made it into their sixties without suffering from any severe lung problems.

And there was more. Wijmenga points to other examples in the data, such as the 177 people in her study who should by rights have a genetic disease called





ABOVE: The tests by the Dutch team found some surprising genetic mutations among the population

LEFT: SERPIN A1 is the gene that provides instructions for making a type of protein (blue) that blocks the activity of certain enzymes (green). When there are faults with SERPIN A1, structures in the body can break down

pseudoachondroplasia. The condition leads to unusually short stature and joint pains. But most of the individuals were just fine.

The list goes on: Wolfram syndrome (high blood sugar, sight and hearing loss); Wilson disease (liver problems and psychiatric issues); Niemann-Pick disease (nerve problems and failure to grow properly in childhood), and more. There are hundreds of healthy Dutch people going about their daily lives, defying the faulty genes within them.

A similar study by Prof David van Heel and his team at Queen Mary University of London came out in March 2016, looking at the DNA of more than 3,200 British Pakistanis living in east London. It revealed 38 people carrying faulty or missing versions of genes linked to serious diseases.

Yet the majority were perfectly healthy. In the close-knit Pakistani community, where there are high levels of marriage between blood relatives, there's an increased chance that people will inherit two dodgy copies of a given gene. And although there are definitely higher levels of genetic diseases in this group, they aren't as high as might be expected.

Similarly, a 2015 study on the genetically reclusive Icelandic population revealed that nearly 8 per cent of the island's inhabitants carry two copies of 'bad' versions of disease-causing genes, but many of them are perfectly fine.

These findings aren't just limited to humans either. Researchers have discovered dogs carrying a genetic variation that protects them against the

doggy version of Duchenne muscular dystrophy.

### REAL SUPERHEROES

Then in April 2016 came the big one. "Thirteen anonymous genetic superheroes walk among us," proclaimed the headlines, reporting on an impressive analysis of more than half a million people's genetic make-up. A team of US researchers known as the Resilience Project discovered that this lucky handful carry mutations that should leave them with serious illnesses, yet are somehow perfectly healthy.

Led by Dr Rong Chen at the Icahn School of Medicine at Mount Sinai, New York, along with Dr Eric Schadt and Prof Stephen Friend, the scientists trawled global databases containing information ➤



## GENES AND MUTATIONS: A QUICK REFRESHER



### What is DNA?

DNA is the genetic instruction manual in our cells. Genes are stretches of DNA that act as 'recipes' for making molecules called proteins, which build our bodies and keep them working.

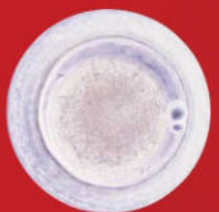
### What is a mutation?

Changes in genes (mutations) can affect the protein they encode, making it more or less active, or causing disease. For example, if you have a mutation in the gene BRCA2 (pictured), you have a higher risk of breast cancer.



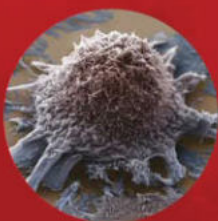
### How do mutations happen?

Mutations can be inherited or can occur when eggs and sperm are made, or in the fertilised egg (pictured left).



### Can adults get mutations?

Mutations can occur in the DNA within cells in the adult body. While these changes can't be passed on to the next generation, they can lead to diseases. For example, smoking damages DNA, which can cause lung cancer (pictured).



### Should I worry?

As well as rare disease-causing mutations, we each have thousands of minor genetic changes – known as variations – that have lesser effects on our bodies, brains and health.



● about people's DNA and whether they were affected by any illnesses. The team focused on mutations responsible for childhood genetic diseases, known as highly penetrant Mendelian diseases (see box, right), where carrying two copies of a faulty gene, or even just one in some cases, is enough to cause severe effects.

To start with, Chen spotted around 15,000 individuals who could be heroes, carrying 'bad' mutations in nearly 200 genes linked to more than 160 severe diseases. Further analysis narrowed this down to 300 people, finally ending up with strong evidence for the existence of just 13 who were resilient to a selection of eight genetic conditions.

Three were resistant to cystic fibrosis, a serious disease affecting the lungs and other organs. Another three were unaffected by gene faults that should have caused major bone abnormalities, known as atelosteogenesis. Two were immune to the impact of mutations

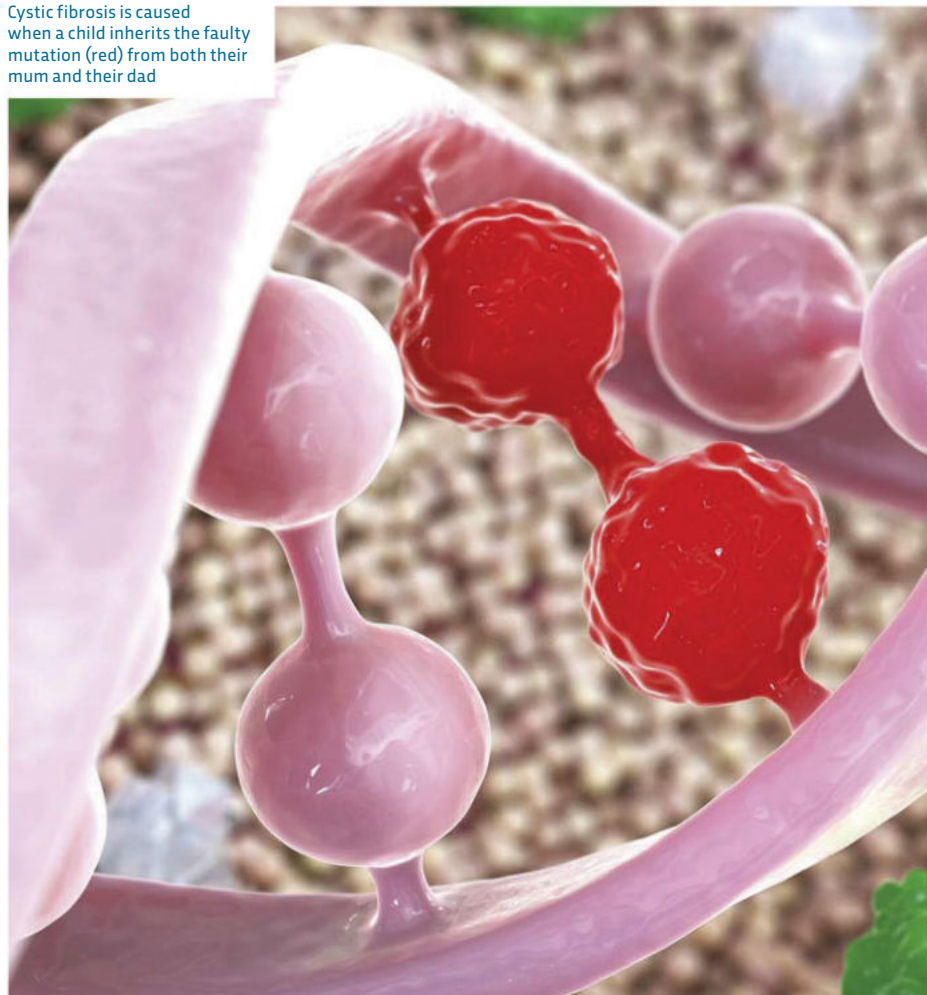
in a gene called DHCR7, usually responsible for a severe developmental disorder known as Smith-Lemli-Opitz syndrome. Another five had their own unique genetic superpowers against a selection of brain, bone, skin and auto-immune diseases.

### HOLDING OUT FOR A HERO

Frustratingly, the identities of these masked men and women will remain a mystery. Due to anonymisation and lack of the right consent to re-contact the people in the databases, the Resilience Project wasn't able to track any of them down for further investigation. This problem has led to some criticisms of the study: there's still a chance that there may have been identity mix-ups along the way (not unusual in such large-scale projects) or that they do actually have mild or even more severe forms of the conditions they appear to have evaded.

There may be other issues too. The biggest is the mutation

Cystic fibrosis is caused when a child inherits the faulty mutation (red) from both their mum and their dad



database itself. This is the resource that lists all the genetic faults known to be linked to diseases. This makes Wijmenga sceptical about the powers of many of the individuals she found in her study.

“All of them are disease genes, but some of them are really common in the Dutch population, and that makes you wonder if those are true mutations or they just ended up in the database in the past but don’t actually cause disease,” she says. “For some of these variants, around 90 per cent of the people have the mutant version, which doesn’t make sense if it’s a real mutation. These things should be rare. So this tells us that the databases aren’t that good.”

That said, there’s still evidence that some superheroes, at least in the genetic sense, are real. And although the identities of those in the Resilience Project’s first study will never be known, the next phase promises to bring a new generation of heroes into the spotlight. The plan is to recruit up to a million people from the general population, find the superheroes among them, figure out how they got their powers, and work out how to harness them for good.

“At this point it still sounds rather ambitious and crazy to say things like that,” explains Jason Bobe, founding director of Harvard’s Personal Genome Project, who’s been brought in to head up the search. “It’s like claiming that you have a platinum record without first writing a hit song, and the challenges of reaching a large number of people are serious.”

He’s after three types of people to get involved, signing up through an interactive app that will take them through consent forms and questionnaires – almost like Facebook for genetics – evolving over time into the most ambitious genetic research project ever undertaken. The first group of people who Bobe is keen to

## *The plan is to recruit up to a million people from the population, find the superheroes among them, and figure out how they got their powers*

hear from is those who have reason to believe they are a superhero and are resilient to disease. In some cases, they may have incredibly strong evidence for this.

“For example, we’ve found a guy who has a really strong family history of early-onset Alzheimer’s disease, which is typically fatal within 10 years. He’s had a dozen family members die of this disease, which only takes one mutation. He’s almost 70 now and figured that he dodged that genetic bullet,” explains Bobe. “So he joined a research study and to his surprise he discovered that he actually has the very same mutation that killed so many of his family. Then the question becomes what’s so

special about this guy? How did he get lucky?”

Bobe is also keen to attract people who have no reason to believe they’re superheroes, just regular genetic Joes with no strong family history of disease, but who are interested in finding out more about their genomes and getting involved in research.

Falling into the third category are those people who are affected by a serious Mendelian disease, because they’re clearly not resilient.

“If you’re actually suffering from the disease there’s still a role for you too,” Bobe explains. “We would love to have the participation of people dealing with and managing these diseases to serve sort of as a ●

### MENDELIAN DISEASES

## ONE GENE, ONE DISEASE?

*Just one copy of a faulty gene is enough to cause a genetic condition*

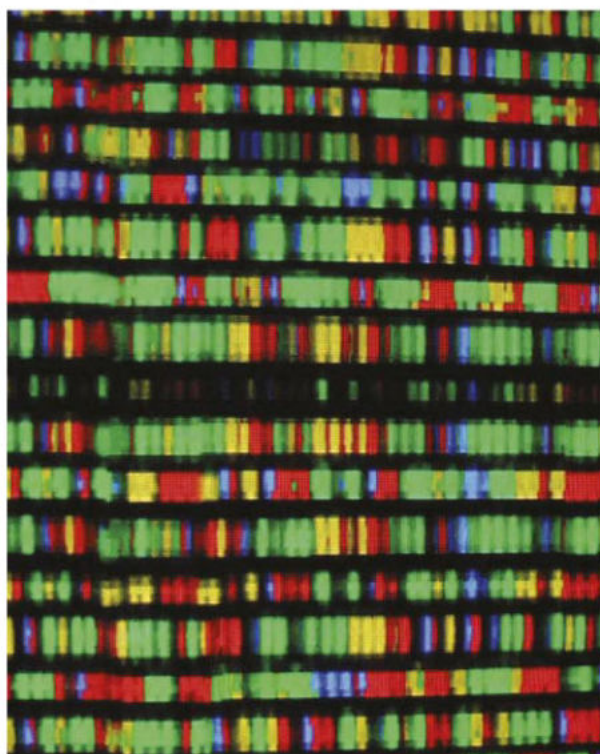
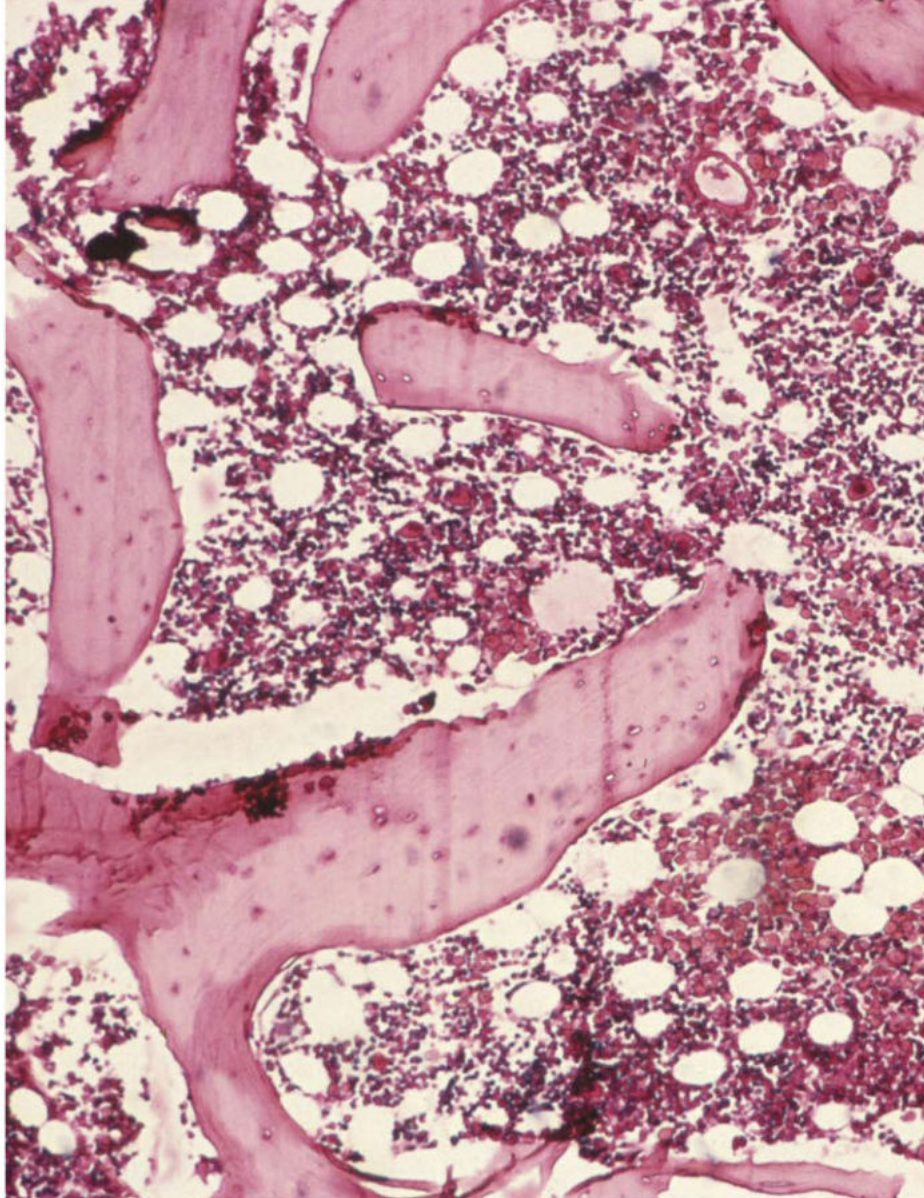
We inherit two copies of every gene, one from mum, the other from dad, and they are not necessarily the same. Scientists have discovered hundreds of diseases that are caused by inheriting either two copies of a faulty gene, known as recessive mutations, or just one (a dominant mutation). These are known as Mendelian diseases, after Gregor Mendel (pictured) who first laid down rules about how traits are inherited. Recessive mutations usually break the gene’s function, so people with one copy are unaffected as their remaining healthy gene can compensate. But even inheriting two recessive or one dominant Mendelian disease fault doesn’t necessarily mean someone will be severely affected. Genetic superheroes are at the extreme end of this spectrum, carrying ‘bad’ gene faults but appearing to be healthy.





BELOW: Dr Cisca Wijmenga is leading the Dutch study into genetic superheroes

BOTTOM: In this digital representation of the human genome, each colour represents one of the four chemical components of DNA



*“In the past we had this kind of black-and-white idea about genetics but now there are all shades of grey”*

● National Guard, so when we do find somebody who resilient to cystic fibrosis, we would love to call upon all those individuals with cystic fibrosis to serve as controls in the decoding.”

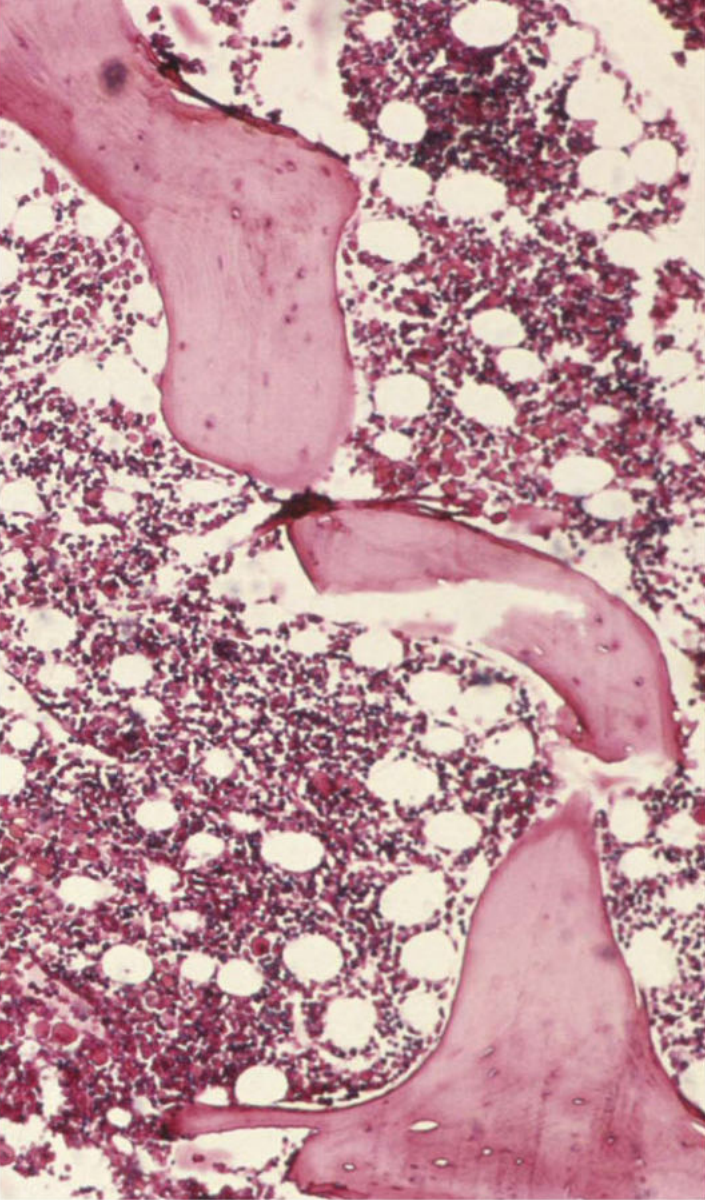
### DECIPHERING THE DATA

It's this part, the decoding, where things get really hard. As the previous studies have shown, superheroes are out there and are relatively easy to find. But the big challenge is working out how they're doing it. Take the example

of the man who dodged the Alzheimer's bullet.

“It's what I like to call a smoking airbag, the opposite of the smoking gun. This guy has had an airbag in his biology that has gone off and we need to find it, but it's looking for the needle in the haystack. What other genetic or environmental factors in this guy's life have enabled him to escape this disease, where in every other case that we've seen it's been fatal,” explains Bobe.





“Now that we have molecular tools like whole genome sequencing, we can generate a lot of data on this one person and try to identify the factor that’s providing protection. Because if we can identify something like a protective mutation that’s actually fending off this heritable disease, then we can identify either preventive strategies or maybe develop new therapies.”

The environment may also play a role in determining whether someone succumbs to the effects of a mutation or not. That could cover anything from a person’s diet and lifestyle to the womb where they grew from a single cell into a baby. It’s this aspect that most excites Wijmenga.

“In the end there are still people running around with these mutations but still have no disease,” she says. “I think if

**ABOVE:** Niemann-Pick disease causes a fatty substance called sphingomyelin to accumulate in the body, as seen in this bone marrow. Some individuals in the Dutch study had the genes for it, but are seemingly healthy

we found out that this is environmental, then that’s even better. If you can find out what those environmental factors are, you have much better ways to treat people with ‘bad’ genes. It is much harder to change your genetics than your environment.”

Whether it’s nature, nurture or a combination of the two, the existence of genetic superheroes tells us that strictly Mendelian ideas about one gene fault always leading to one disease are far too simplistic. Now we’re starting to rifle through the genes of the fit and well, we’re finding all kinds of surprises. For a start, we need to start viewing people who carry genes for ‘pure’ Mendelian diseases as existing along a spectrum, ranging from severely affected at one end to superheroes at the other. And in fact, everyone’s a bit mutant, carrying up to 40 ‘bad’ gene faults.

As head of a clinical genetics department, Wijmenga finds this ambiguity challenging. “We’re dealing on a daily basis with patients,” she says. “We sequence their genome and find a mutation, and we have to predict what we think that means. It’s important that we have a much better understanding of our genome and when a mutation matters and when it doesn’t. In the past we had this kind of black-and-white idea but now there are all shades of grey. It’s an interesting time to be a geneticist, I would say!”

**Kat Arney** is a London based science writer and broadcaster. Her first book, *Herding Hemingway’s Cats: Understanding How Our Genes Work* (£14.99, Bloomsbury Sigma) is out now.

#### DISCOVER MORE



Watch an episode of *Panorama* that explores the medical breakthrough of gene editing at

[bit.ly/gene\\_editing](http://bit.ly/gene_editing)

## HERO HUNT

# ARE YOU A GENETIC SUPERHERO?

The Resilience Project is planning to begin its first phase of recruitment in autumn 2016. It will initially launch in the US, before expanding to other countries. It will take people through a short survey to assess their chances of being resilient to genetic diseases. Find out more and sign up for updates at [resilienceproject.com](http://resilienceproject.com)





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# THE MOST **EXTREME** JOBS IN SCIENCE

*From crocodile behaviourist to faecal transplant technician,  
we look at some of the most extraordinary jobs in science*

WORDS: KATHERINE NIGHTINGALE AND JO CARLOWE

## THE LAVA LOVER

NAME: Dr Hugh Tuffen

JOB TITLE: Volcanologist

BASED: Lancaster University, UK

“ I first became interested in volcanoes when I was about seven. I slept with a volcano picture book under my pillow.

There have been concerning moments. One night in Chile, heavy ash and pumice rained down on our camp and we had to decide whether to stay or go. Or there was the time we were digging increasingly desperately into the mountainside to find uncontaminated snow to melt for drinking water. I also spent months camping in Iceland for my PhD, enduring days of wind and rain. It's not much fun putting on wet clothes for the fourth day in a row, but the exquisite beauty and isolation of the environment makes up for it.

I study what makes volcanoes explosive and how the gas trapped in magma drives violent eruptions, forcing out lava and throwing ash kilometres into the air. We're also trying to figure out what controls the way that lava flows, in the hope of helping people who live in its path. This means travelling abroad to erupting volcanoes, often at short notice, to witness these explosions.

Sometimes it's possible to walk up to lava as it flows and take samples with a shovel. Back in the lab, we'll heat a sample to over 1,200°C so it'll behave like it's in the volcano. This means we can see what's happening on a microscopic scale.

Knowing that my work can help lots of people is motivating. But it's annoying that there are far too many interesting volcanoes to study, and that's before you even include the ones on other planets and moons in our Solar System.

”



# THE CROC PSYCHOLOGIST

NAME: Cherie Chenot-Rose  
 JOB TITLE: Research biologist and  
 co-founder of American Crocodile  
 Education Sanctuary  
 BASED: Florida and Belize



PHOTO: SHAWN RENER/UNDERWATER DIGITAL IMAGES, GETTY

“ I’ve been bitten by three species of crocodilians, and one broke my shin with a whip of its head. I don’t carry a weapon but my teammates have large knives. Our intent is not to harm the animal, and we never have, but human safety always comes first.

We normally get called out when a crocodile is under someone’s home. We wait through the night, wet, muddy and stinking of rotten chicken, which we use to tempt the crocodile out. Then, game on! My husband, Vince, snares the croc and drags it onto land while I position myself behind it. When the time is right, I leap onto the head of the animal. An assistant secures the back legs, then we tie up the croc, collect data and tag it before releasing it. If people’s safety is at risk, we relocate the croc, or place it into captivity.

To know how to respond, we need to study the behaviour of the animals. The crocodile to worry about it is the one at the water’s edge, totally submerged but for the tip of its nose, watching you through its translucent third eyelid. While you are distracted, it’s waiting for the right moment to strike. A croc can strike three times faster than a rattlesnake.

One time, while capturing a three-metre male crocodile, the rope broke. I felt the vibration from its teeth smashing together just inches from my upper thigh. Crocodiles smack their jaws together so hard that they can shatter their own teeth.

The toughest part is not capturing the crocodiles, it’s obtaining funding. The most rewarding part of my job is rescuing an injured crocodile, rehabilitating it and setting it free. ”

## THE GUT

## DETECTIVE

NAME: Dr Enid Taylor  
 JOB TITLE: Clinical director of the  
 Taymount Clinic for Digestive Health  
 BASED: Hertfordshire, UK

“ The first time a caller asked if we did faecal transplants, I was so horrified I cleaned the phone in disdain. Back then, the Taymount was a naturopathy clinic, but my husband, Glenn, had a light bulb moment – he saw faecal microbiota transplant (FMT) as the answer to a huge problem, and the FMT clinic evolved from there. We now use FMT to treat patients with various gut conditions.

We extract good bacteria from donor stool and refine it. We wear protective clothing as nobody wants to be splashed in poo, refined or not! Early in our equipment development, a tube blew out of a lid and a jet of liquid faecal material shot into the ceiling extractor. We had to laugh as the s\*\*t really had hit the fan!

ABOVE: A member of Cherie’s team holds one of the smaller residents at the American Crocodile Education Sanctuary





## THE SPIDER MILKER

NAME: **Steve Trim**

JOB TITLE: **Founder of Venomtech**

BASED: **Sandwich, UK**

Once we've refined the donation, we ultra deep-freeze it. When it's ready to be used, it is thawed, warmed and introduced into the patient's body using a rectal catheter. There's little smell as it's all contained within syringes. During administration, you have to be gentle; I get the patient to lie in relaxing positions and talk to them about diet and how to look after their new internal 'pets'.

It's a personal journey that brought me into this work. I had irritable bowel syndrome, and have always been interested in food and digestive health. When you painfully need the toilet every 45 minutes, it's hard to keep a job and maintain relationships. Helping people regain normal function is heart-warming.

When people ask what I do, I take a deep breath and decide whether to give the short answer or the longer, more scientific one. Sometimes, I joke that I'm a 'poo doctor'. My husband and I have five grown-up children. At first they didn't know what we did, but now they ask advice. I have a sneaking suspicion they might be a little bit proud.

”

ABOVE: A steady hand, a tiny collection tube and a respect for animals are necessary requirements for milking a venomous spider

“ Keeping spiders and reptiles fascinates me. I kept non-dangerous spiders and snakes as pets, but following redundancy, I used my previous experience working in pharmaceuticals to set up Venomtech in the back of a pet shop in Ramsgate. Six years on, we now occupy a large lab.

Venomtech is the UK's only commercial venom supplier. We collect venom from: 70 species of theraphosidae, which is a family that includes tarantulas; 30 scorpion species; several true spiders such as black widows, brown recluses and Brazilian wandering spiders; jellyfish and anemones; centipedes; millipedes; some ground beetles; and 65 species of venomous snakes.

Clad in lab coats, gloves and safety glasses, we hold the snakes behind the head using a handling tool. They are happy to deliver venom into anything in front of them, including our polypropylene pots.

The toughest work is with small spiders such as black widows (the most toxic creature in our lab). Their fangs are so tiny, you need a steady hand, great discipline and a methodical approach. We place their fangs into little collection tubes and stimulate the venom glands with tiny electrical impulses. If the venom misses, it is unusable. Even anaesthetised, black widows are handled with forceps and given a constant flow of CO<sub>2</sub> to ensure they stay asleep.

My family worries, but my wife shares my passion for venomous animals, and we have not had any incidents. The best part is seeing our venoms killing *E. coli* and *Staphylococcus*, which could help with antibiotic resistance.

”







Forensic entomologists study the insects that colonise dead bodies

## THE INSECT INVESTIGATOR

NAME: Dr Amoret Whitaker  
JOB TITLE: Forensic entomologist  
BASED: University of Winchester and the Natural History Museum, UK



Amoret needs to understand all stages of insect development, to help her determine how long a person has been dead for

“ The first time I looked at insects down a microscope at university, I thought they were amazing. I’d never really thought about insects before, as I wasn’t one of those kids who was collecting butterflies from an early age. I began my zoology degree imagining I’d end up saving big, furry animals.

I study insects in a legal context, usually the flies and beetles that colonise dead bodies. It’s a mixture of research, where I study the development of flies and beetles in different conditions, and work with the police, where I use that knowledge to determine when a person died. Blowflies are usually the first insects to find a body, so they’re useful for estimating the time since death.

In this job you never know what’s going to happen. There are just a handful of forensic entomologists to cover the whole country, so I’m on call 24 hours a day, seven days a week. Sometimes I can be working on six cases, and other times I might go months without a call-out. I also teach at the University of Winchester, and do research at London’s Natural History Museum and the ‘body farm’ at the University of Tennessee, where corpses are left to decay and studied.

The case work can be distressing. And there are scary moments too, such as working on the body farm at night. It’s incredibly satisfying though, particularly helping bring closure to families. Unlike the three years that I spent studying fleas earlier in my career, no one ever asks me what the point of it is. ”

PHOTO: BARBARA WINTER/SIMON FRASER UNIVERSITY, ROBBIE SHONE





## THE CAVE

## RAIDER

NAME: Dr Hazel Barton

JOB TITLE: Microbiologist


BASED: University of Akron, Ohio

Hazel spends days at a time in cave systems, like this massive one in China, hunting for microbes

“ I started caving back in sixth form at school, long before I became a scientist. When I started working as an environmental microbiologist, it seemed natural to combine the two.

I study microbial ecosystems in deep and remote caves, trying to work out how microorganisms can grow in the dark with so few nutrients. We work at depths of up to 500m – the microbiology gets more interesting the deeper you get. We’ll spend around a week in a cave, exploring its structure and taking samples of microbes. The expeditions are huge undertakings, about as logistically technical as climbing Everest. We rig our own ropes, and carry all our camping gear and research equipment, sometimes through gaps as small as 20cm.

When you spend a week in complete darkness, you have to be careful that your circadian rhythm doesn’t slip into 27-hour days. I make sure that everyone’s in bed by 10pm and up at 7am. On the first few trips you get really cranky because of the lack of sunlight. And you need to make sure that you like and trust the people you’re with. If something goes wrong, your life is in their hands.

The best thing about my job is the travel – as well as the US, we also work in Venezuela, Brazil, Belgium and China. You never know what you’re going to find. In China, we discovered the third biggest cave room in the world by following a river into a mountainside and ending up in a vast space 600m long, 200m wide and 400m high. It was an incredible feeling. 





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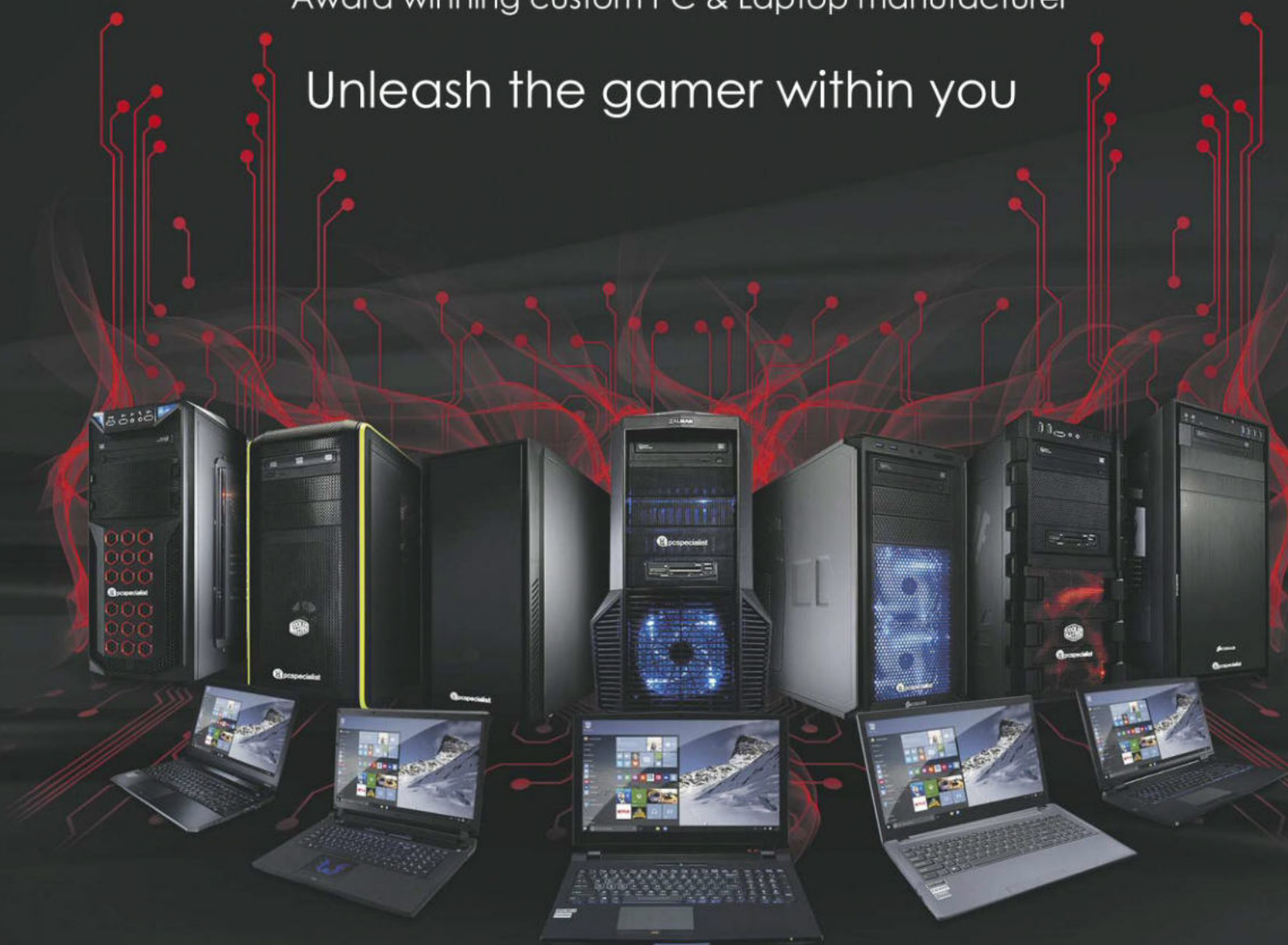
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# THE ARTIFICIAL MEAT FACTORY

*Three years ago, the first lab-grown burger was served up. So where are our synthetic steaks? We look at the race to mass-produce artificial meat*

Words: Tom Ireland



Currently, animals are farmed for their meat (this page) but a bioreactor (opposite page) provides ideal conditions in which to grow muscle cells to create cultured meat





DON'T MISS  
**THE FOOD  
WE EAT**  
BBC TWO, THIS AUTUMN





**B**ack in 2013, the world watched as food critics tucked into the first ever lab-grown burger. The small pink patty, prised out of a petri dish and fried in front of the media, was proof that it was possible to grow safe and edible meat without slaughtering a single animal. There was just one problem: the patty had taken two years and over \$300,000 to produce.

Yet, in less than three years, the cost of producing this high-tech meat has plummeted. Last January, a company called Memphis Meats produced a 'cultured meatball' for around \$1,000, and today start-ups and non-profit organisations are working on other lab-grown animal products including pork chicken, turkey, fish, milk, egg whites, gelatin, and even leather.

Dr Mark Post, the Dutch scientist who created the \$300,000 burger, believes it would be possible to make improved

versions of the patties for around \$10 each if his technology could be scaled up to the level of an industrial food process.

So how long will we have to wait until we're able to buy artificial sausages and steaks in our supermarkets? Will they taste like the real thing, and will anyone actually buy them?

### A LOT AT STEAK

Lab-grown meat, or more accurately, 'cultured meat', is made by growing muscle cells in a nutrient serum and encouraging them into muscle-like fibres.

RIGHT: Dr Mark Post's original cultured burger contained no fat, so it was 'a bit dry', according to food critics

BELOW: Dutch scientist Dr Mark Post with his lab-grown burger



Simpler animal products, such as artificial milk or hen-free egg whites, can be created by yeast that has been genetically altered to produce the proteins found in milk or eggs, which are then extracted and blended in the right amounts.

In fact, using 'cellular agriculture', there's no reason why scientists couldn't grow meat with characteristics from a combination of animals, or enhance lab-grown meat with healthier fats, vitamins or vaccines. We could even taste the flesh of rare animals that nobody would dream of slaughtering for food. Panda burger, anyone?

For now, the race is on to make the first affordable cultured meat products. The need to find credible alternatives to traditional meat is urgent. Livestock farming takes up a huge amount of land and water per calorie of food compared to crops, and in terms of greenhouse emissions, is as bad as burning fossil fuels, according to the UN. Rising incomes in developing countries means that more people are eating meat than ever before, reducing the amount of land available for much-needed crops, and contributing to climate change. Of course, being able to grow meat artificially can only have a positive impact on animal welfare, too.

So when will we be able to buy animal-free meat? Both Memphis Meats and Mosa Meat, an offshoot of Post's lab, hope to have competitively priced products by 2020. "In terms of commercial sales, I would say in four to five years," says Post. "It will still be a somewhat expensive burger, around the \$10 mark. Another few years of commercial production and the price will start to fall further."

### MANUFACTURING MEAT

The science behind growing meat without animals is fairly simple. Growing the cells that form cultured meat is not hugely





different from other 'cell culture' methods that biologists have used to study cells since the early 1900s.

The process starts with a few 'satellite' cells, which can be obtained from a small sample of muscle taken from a live animal. These are stem cells that can turn into the different cells found in muscle. Just one cell could, in theory, be used to grow an infinite amount of meat. When fed a nutrient-rich serum, the cells turn into muscle cells and proliferate, doubling in number roughly every few days.

After the cells have multiplied,

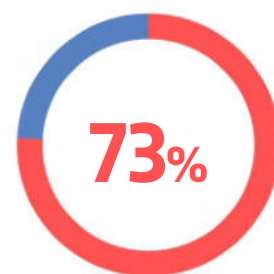
they are encouraged to form strips, much like how muscle cells form fibres in living tissue. These fibres are attached to a sponge-like scaffold that floods the fibres with nutrients and mechanically stretches them, 'exercising' the muscle cells to increase their size and protein content. The resulting tissue can then be harvested, seasoned, cooked and consumed as boneless processed meat.

The challenge facing Post and others in the field is upscaling the process. To grow cells industrially requires a large •

ABOVE: Memphis Meats developed this \$1,000 meatball earlier this year

***The need to find alternatives to traditional meat is urgent, as livestock farming takes up a huge amount of land and water***

## FACTS TO CHEW OVER



Is the amount global meat consumption is forecast to rise by 2050, due to growing incomes and urbanisation in developing countries.

## 9.7 billion

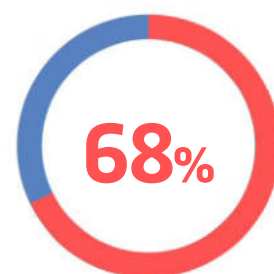
The estimated population of Earth in 2050. Growing enough food to feed a rapidly increasing global population is already a pressing concern.

## 15,000 litres

The water required to make 1kg of (farmed) beef, compared to 2,500 litres for 1kg of rice.

## 7.1 trillion kg

The CO<sub>2</sub> equivalent contribution of global livestock farming per year. This represents 14.5 per cent of all anthropogenic greenhouse gas emissions.



The proportion of people who said they wanted to try cultured beef following the presentation of the world's first lab-grown burger.



## WOULD YOU EAT LAB-GROWN MEAT?

"I wouldn't want to eat something so similar to meat, even if there was no cruelty involved. Putting so much energy in this direction also perpetuates the myth that meat is necessary and desirable. But if it's marketed as an accessible product, it could have great consequences for the environment and animals."

Elena Orde, editor of *The Vegan*

"While the science of lab-grown meat is interesting, the National Farmers' Union believes there is great potential for farming to be sustainable and more efficient, to reduce emissions and feed a growing population while offering benefits to the environment, landscape and the rural economy."

Dr Helen Ferrier, NFU's chief science adviser

"If it becomes possible to produce cultured meats that have a similar taste, texture and nutrition to 'real' meats, then I would embrace it fully. In order to be allowed on sale, it would have to undergo extensive testing. The only reason that I can see for people to reject such a product would be a blind, technophobic fear of progress."

Anthony Warner, chef/food writer

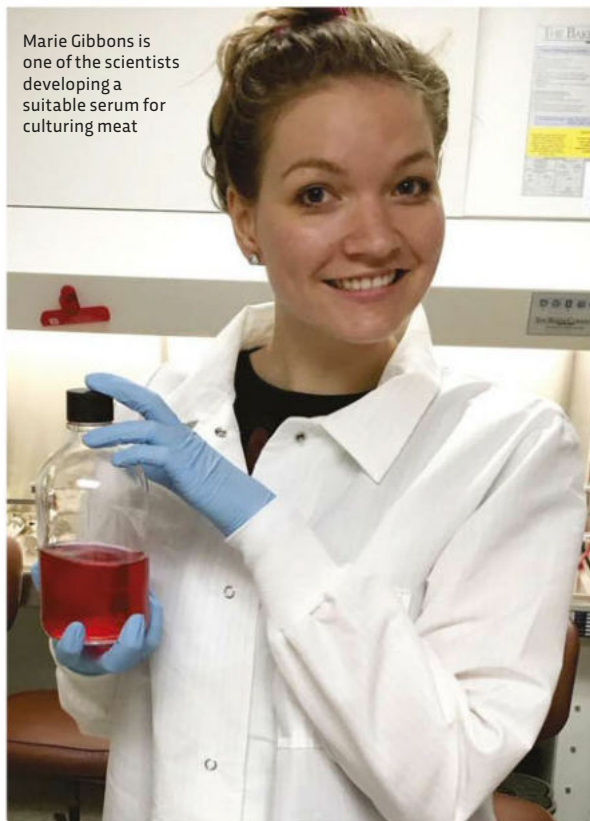
cocktail of sugars, amino acids and animal blood. Not only are blood-based serums a source of worry for vegetarians and vegans, but "there would not be enough serum in the world to grow all the cells you need to mass-produce," says Post.

He and other cultured meat companies are working on blood-free alternatives – but it's not simple. "We are working out which substances in blood are required for growth," he says. "There are tens of thousands of different substances in blood and there are a few magical ingredients required for every different cell type."

### A QUESTION OF TASTE

Achieving a taste and texture that rivals real meat seems to be the easy bit. Following a comment from the critics who tasted his original burger and said it was a bit dry, Post has started to culture fat cells and tissue from cows, which add moisture when mixed in with the muscle fibres. He has also discovered that starving the cells of oxygen can increase the amount of flavour-giving proteins in the final product.

Marie Gibbons, a researcher from North Carolina State University working on cultured meat production, says there is no limit to what scientists could do with flavour. "There's no doubt that [cultured products] can be manipulated to achieve good flavour – it's just a case of what chemicals react with your taste buds," she says. She thinks cultured meats could eventually be



Marie Gibbons is one of the scientists developing a suitable serum for culturing meat

• 'bioreactor' – a high-tech vat that can provide the perfect conditions for growth but also the movement and stimulation to exercise the cells. The largest existing bioreactor capable of doing this has a volume of 25,000 litres (about one-hundredth the size of an Olympic swimming pool), which Post estimates could produce enough meat to feed 10,000 people. It's likely that many more of these would be needed to make a viable meat-processing plant.

An alternative idea is to encourage shops and restaurants to grow their own meat on a smaller scale. SuperMeat, an Israeli biotech company, recently launched a crowdfunding campaign to raise \$100,000 to develop cultured-chicken-growing devices that could be "placed at grocery stores, restaurants, and ultimately in consumer homes".

Another issue is the nutrient-rich 'serum' that feeds the cells. Successful serums have been a

### TOMORROW'S FOOD

Turned off by manufactured meat? Here are five other foods that could soon be gracing your plate...



#### SYNTHETIC MILK

Companies such as Muufri are close to perfecting cow-free milk. Milk-producing genes are inserted into yeast, which are then bred in vast numbers to produce milk proteins.



#### INSECT INGREDIENTS

Insects are a sustainable protein. While many may not be persuaded to eat them, it's likely that consumers will start finding ingredients such as flour made from crushed crickets in their food.



#### APPETISING ALGAE

Seaweed grows quickly and is a core part of Japanese diets. As it can be grown at sea, it would solve the issue of dwindling land for crops. There are thousands of varieties that could be farmed and eaten.



#### DOWNLOAD DISHES

3D printing is already used to create fancy structures in high-end sweet-making. If 3D printers continue to advance, people will be able to download a recipe and 'print' their own meals.



#### DODO KEBABS

As tissue engineering and GM techniques progress, it may be possible to combine characteristics of different animals into entirely new meats, or even produce the flesh of extinct animals in the lab.





ABOVE: Could these signs be seen in future butcher shops?

tastier than traditional meat, although she adds: “At the moment the priority is to produce edible protein on a large scale. Then you can work on flavour components.”

The first crop of cultured meat products will inevitably take the form of burgers, nuggets and other processed meats – unprocessed meat has a complex structure of bone, blood vessels, connective tissue and fat, and grows in specific shapes. Yet it should eventually be possible to grow complex tissue like this too, says Dr Paul Mozdziak, Gibbons’s colleague at North Carolina State University. He and scientists at various cellular agriculture organisations (such as New Harvest, SuperMeat and Future Meat) are keeping an eye on developments in regenerative medicine, the branch of biomedical science concerned with growing replacement organs and tissue for procedures such as skin grafts.

Regenerative medicine involves encouraging cells to grow on a scaffold so the resulting tissue mimics the precise layout of a living organ, with different types of cells in the right position, creating interconnecting, functional parts. However, the complexity of living

tissue means that only relatively simple tissues like skin have been made with any success.

Still, a lab-grown pork chop or rack of ribs is perfectly feasible, says Mozdziak. “When the cultured meat and scaffolding worlds collide, then the industry will take off exponentially,” he says.

As well as animal parts for food, scientists could even grow organic items such as rhino horns in order to help prevent poaching.

#### WHAT’S THE BEEF?

In the shorter term, with more basic cultured meat products predicted to be ready by the turn of the decade, a bigger question may be whether people are ready to eat the stuff. Will consumers drink synthetic milk and eat lab-grown meat, or will they be put off? Genetically modified foods, for example, are still mistrusted by many.

Organisations such as the Modern Agriculture Foundation are already preparing the ground for the arrival of cultured meat, educating people about why we need it. The Foundation’s director, Shaked Regev, believes that cultured meat won’t have the same problem that existing meat alternatives face

because it is so similar. “It’s the real deal – you can’t differentiate this from traditional meat under a microscope,” he says.

Polls suggest there’s a willingness to give this modern meat a go. One survey of the Dutch population indicated that 63 per cent of people were in favour of the concept of cultured beef, and 52 per cent were willing to try it. Another survey by *The Guardian* found that 68 per cent of people wanted to try cultured meat. Whether people reach for the cultured burgers week in, week out at the supermarket is a different matter entirely, though.

People will always be extremely sensitive about what is on their plate. Despite the welfare and environmental justifications for cultured meat, the thought of your burger coming from a lab rather than a farm is a strange idea. But if cultured meat lives up to its promise and becomes the environmentally friendly, safer, cheaper, and even tastier way to eat meat, the concept of raising animals in their millions for slaughter could very quickly seem much stranger. **E**

**Tom Ireland** is a science writer and managing editor at the Royal Society of Biology.





# HOW SAFE IS YOUR PLANE?

It's that time of the year when many of us take to the skies. We look at the rigorous tests that planes undergo to ensure flying remains one of the safest modes of transport

Words: Neil Ashton

Air travel is more popular than ever – last year saw more than 1.5 million flights pass through the UK alone. Although aeroplanes have made it easier for us to explore the world, nearly one in three of us claims to be anxious or fearful of flying. Is this fear justified?

US statistics taken from between 2000 and 2009 show that car drivers or passengers suffer 7.3 deaths per billion miles. In contrast, air travel comes in at just 0.07 deaths per billion passenger miles. Of course, statistics can't cure someone's fear of flying, but they do prove that it's one of the safest ways to get from A to B. This safety is thanks to the testing that every single part of the aircraft has to go through before it's allowed to undertake its first flight.





## IN THE FREEZER

While passengers get to enjoy the comfort of air conditioning, the engines have to be able to cope with temperatures as low as  $-55^{\circ}\text{C}$  during cruise conditions. Here, one of the latest engines is being pushed to its limits at a General Electric testing facility in Winnipeg, Canada. It's being blasted with icy water from hundreds of nozzles at sub-zero temperatures to check that it will maintain power in cold environments.

Temperature tests are important to the airlines because they want to make sure that their planes can operate in as many environments as possible. Each time they have to ground an aircraft because of bad weather, they lose money. ●



## TURBULENT TIMES

For many, turbulence is one of the greatest contributors to the fear of flying. But while turbulence can be uncomfortable, most of the time the plane is moving very little, and is well within the design limits. Rarely, severe turbulence can cause a sudden drop in altitude, resulting in a strong upwards force on the wings. Therefore, manufacturers design the wings to tolerate far higher loads than would ever be seen in reality. Here, a Boeing 787 is being subjected to a 'maximum stress' test, where the wings are exposed to over 1.5 times the normal load, bending in excess of 7m. Even then, the structure didn't break, which should give some reassurance the next time you're worried about wobbly wings.





## SAFEST SEATS ▼

Travellers often wonder which is the safest place to sit. Is it the front of the plane, the middle, or the back? In 2012, a TV production company bought a Boeing 727 and crashed it into the Mexican desert to find out. The craft hit the dirt at 257km/h (160mph). While the front broke off, the rest of the plane came to a halt with relatively little damage.

They concluded that individuals in the first 11 rows would have died, but that 78 per cent of the other passengers would have survived. But before you clamour for a place at the back, rest assured that manufacturers use sophisticated modelling tools to optimise the ability of the entire structure to withstand unexpected landings on land or sea.



## BEWARE THE BIRDS ▲

On an outdoor test stand at General Electric's Peebles testing facility in Ohio, a new engine is being put through its paces. It's about to be splattered by a high-speed bird carcass, to simulate a bird strike. Migrating birds can travel at altitudes of over 8,000m and threaten the cruise phase of the flight, although the greatest risk is during take-off, when the craft is at its heaviest and the engines are close to maximum power. The bird cannon test makes sure that the engine can either continue working or successfully shut down after a physical strike, limiting the risk of an explosion. If the engine fails the test, it's time to go back to the drawing board. ☛



## COLD COMFORT ▶

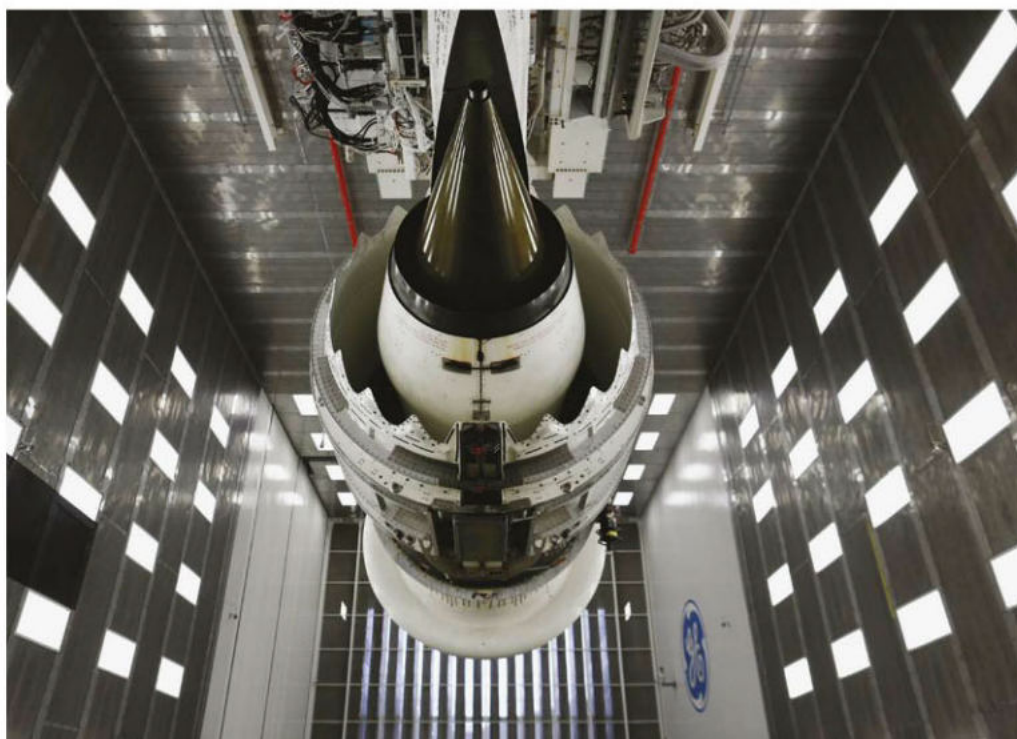
No, it's not the strangest package holiday in existence. These mannequins are part of an experiment to improve the comfort of long-haul air passengers. They're equipped with temperature sensors, helping engineers at the German Aerospace Centre to design a new ventilation system. With more electronic devices being used inside cabins, improved ventilation systems are needed to remove the extra heat. The system being tested here delivers low-speed air from inlets in the floor, rather than pumping in air from the cabin's roof as in conventional aircraft. This cools the plane without causing cold draughts.

## ENGINE ROOM ▼

This mechanical marvel is one of General Electric's latest jet engines, undergoing testing at the Peebles facility in Ohio. The 5.6-tonne GEnx-2B engine is used on the Boeing 747, delivering around 67,000lb of thrust – the equivalent horsepower of more than 700 small hatchbacks. The testing rooms are made from 6m-thick walls of high-density concrete in order to withstand the incredible power of the engine, and are packed full of performance-measuring sensors.

Over the past decade, the desire for greater fuel efficiency has driven aircraft designers to switch from four-engine configurations to just two engines for long-haul aircraft, such as the Boeing 787 Dreamliner and the Airbus A350. These engines are designed to ensure that even if one of them fails, the remaining engine still has enough power to complete take-off and landing.

PHOTOS: DLR GERMANY/ERNSTING, AIRBUS, GETTY







## ▶ WATER WAY TO LAND

Planes are designed to operate in the most extreme weather conditions, from desert heat to rain-soaked runways. Here we see the latest Airbus A350 undergoing 'water ingestion' tests at a facility in Istres, France. These tests assess whether the engines and aircraft systems are able to operate on water-logged runways, where the standing water might be a couple of centimetres deep. In these conditions, huge volumes of water are being sprayed into the engines, so the aircraft must be able to cope with this sudden deluge. 📺

**Neil Ashton** is an aerospace engineer and a senior researcher at the University of Oxford's e-Research Centre.

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## HELEN CZERSKI... **WHY ISN'T THE SEA TRANSPARENT?**

**“WHEN WE LOOK DOWN INTO THE OCEAN, WE SEE ALMOST NOTHING BEYOND THE SURFACE”**

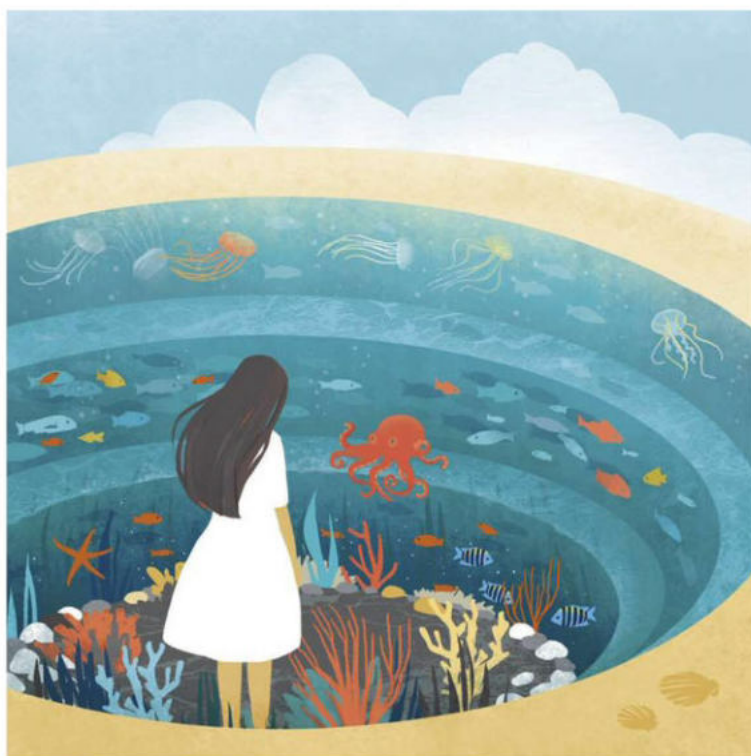
**W**

hen you stand on a beach and look out over the sea, you're faced with two gigantic components of the Earth's engine: the atmosphere and the ocean. Many of us can sit and look at the boundary between water and air for hours, watching it change shape as waves and tides move it around. But we have a strikingly different relationship with the blue below and the blue above. We can look up into the air and see clouds and birds and planes passing by. We know what's going on up there and it's part of our world. But when we look down into the ocean, we see almost nothing beyond the surface. There are all sorts of things down there – fish and kelp, mountains and valleys – but they're hidden. If you scoop up a handful of water, it seems to have no colour – it's transparent, just like the air. So why can't we see into the ocean in the same way that we can see into the air?

The first problem is that we're in the air, looking at the water. It's an odd thing, but the boundary where one transparent object touches another one often doesn't let much light pass through. If you look across the ocean surface, most of what you see is the reflection of the sky. That's because the surface behaves like a mirror when light hits it at shallow angles. The lower the angle, the more mirror-like it is. If you stare into a pond, there's almost no reflection because you're pretty much looking straight down. But if you're somewhere low (like a beach), you get a lot of reflections. It makes sunsets look beautiful, but it's no good for watching fish.

And that's only the start. The light that wasn't reflected off the surface made it down into the ocean and might now be on its way back out. Shouldn't we see that? Sadly, it turns out that physics is against us here too. Firstly, there's a mirror effect from the other side. A lot of the light that's travelling towards the underside of the sea surface is reflected back down into the ocean. But even the light that travels at steeper angles isn't much use to us. As it passes through the boundary, its path is bent, and it turns out that very little of that light comes out sideways at the sort of angle that you might be able to see from a beach. So that's no good.

Finally, light just doesn't travel very far underwater. It can travel hundreds of kilometres through the air



and hardly changes at all. But seawater absorbs light quickly. After just a few metres, 90 per cent of the red light is absorbed, and after perhaps 40 metres, 90 per cent of the blue light is absorbed. So most of the sunlight that might bounce off a fish is absorbed either on its way in or its way out.

As an unashamed ocean enthusiast, fascinated by all the amazing things hidden in the sea, I find this very frustrating. Possibly my favourite thing in the ocean (and there's a lot of competition) is the octopus, an intelligent, colour-changing, puzzle-solving creature, capable of changing shape in an astonishing variety of ways. Who needs aliens from space when you've got octopuses here on Earth? I would love to be able to stand

on a beach and watch the ocean world, this alien place that's right on our doorstep. But I can't. I can jump into the water to look, and when I do that, I cross to the other side of that air-water boundary. During that transition, two things change. I can see the octopus. But the octopus can also see me. **F**

**Dr Helen Czerski** is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, will be out in November.

**NEXT ISSUE: WHY DOES CLAPPING WITH WET HANDS SOUND BETTER?**





## IN THE DARK

The Loch Ness Monster first erupted into public consciousness in the 1930s, at around the same time as acclaimed monster movie *King Kong* hit the cinemas. It would seem that our culture and psychology hardwire us to believe that eerie locations such as deep lakes and dark forests could conceal frightening monsters.





# HOW DO WE KNOW...

# THAT THE LOCH NESS

# MONSTER DOESN'T

# EXIST?

Scientists are pretty certain that there's no such thing as the Loch Ness Monster, or Bigfoot, or Yeti. But how can we know for sure?

WORDS: DR DARREN NAISH

# A

ugust 1933. It was a warm summer's day when Mr and Mrs Spicer were driving along the road adjacent to Loch Ness. Suddenly, lurching from left to right across the road, appeared an amorphous, monstrous apparition that moved with a peculiar bounding motion. An object that looked like the head of a small deer was located somewhere about its middle.

The Spicers' sighting was one of the very first to describe the Loch Ness Monster, a creature known more popularly today as 'Nessie'. It's a classic sighting, regarded as part of a field – cryptozoology, the hunt for unknown and typically monstrous animals – seen by its proponents as challenging mainstream science.

The Spicers' account is one of many Nessie sightings, and only one of thousands of monster sightings worldwide. Other famous monsters include Bigfoot (also known as Sasquatch), the Yeti, the dinosaur-like Mokele-Mbembe of the Congo, and the terrifying winged Ropen of New Guinea. But in a way, the Spicer sighting epitomises cryptozoology as a whole. The more we've learnt and the more data we've gathered and analysed, the more it seems that all these accounts have logical explanations.

## SEEING MONSTERS

The Spicer sighting coincided with a specific cultural event, namely the release of the now-classic movie *King Kong*. Don't forget, this film features dinosaurs and other animals in addition to its eponymous anti-hero. Everyone was talking about *King Kong* in the summer of 1933, and we know that the Spicers had seen the movie. They'd been culturally primed: dinosaur-like monsters were metaphorically lurking in their minds.



ABOVE: In the 1960s and 1970s, the Loch Ness Monster was taken quite seriously, and people scanned the lake's shores in the hope of glimpsing the beast

BELOW: 1933's *King Kong* ensured that monsters were at the forefront of everyone's minds



Furthermore, the Spicer sighting can be explained if we just look at enough of the details. The bounding motion, that small 'deer's head', and the location of the encounter (it occurred next to a track in the woods where a vegetated verge meets the road) all indicate that their 'monster' was simply a group of deer bounding in front of them, a fawn in its midst. This is exactly what Rupert Gould, the investigator who brought the Spicer sighting to attention, concluded, later regretting his inclusion of the account in his 1934 book, *The Loch Ness Monster And Others*. ●



➤ Additional Nessie sightings rolled in during the 1930s, laying the foundations for a school of thought in which the monster's existence came to be taken semi-seriously. This phase persisted into the 1960s and 70s. During these decades, rare snippets of film and blurry photographs were put forward as support for the creature's existence. In 1972, underwater photos of Loch Ness appeared to show the flipper of a gigantic, plesiosaur-like creature. Surely, believers said, confirmation of Nessie's existence was but weeks away. This might sound like an optimistic view today, but it shows the extent to which cryptozoology had captured the public's imagination.

The man responsible for much of this excitement was Bernard Heuvelmans. In the mid-1950s, this Belgian-French zoologist published a successful book titled *On The Track Of Unknown Animals*, in which he put forward the case for the existence of mystery beasts neither accepted nor taken seriously by science. He pointed to the 19th- and 20th-Century discoveries of a range of large animals – including the okapi, Komodo dragon and mountain gorilla – as support for his view that other large creatures were still out there to find.

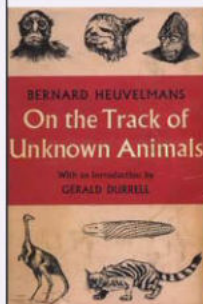
Heuvelmans' writings developed a substantial following. The daring proposal that giant mystery primates, lake and sea monsters, and surviving dinosaurs and pterosaurs might really exist – an idea that had always been present at the fringes of the zoological world but was dismissed due to lack of evidence – achieved a modicum of respectability when its proponents elected to form an International Society of Cryptozoology (or ISC) in 1982.

Over the years, scant fragments of data were put forward as support for the existence of the mystery creatures that Heuvelmans and the ISC endorsed. Key among these were the alleged Nessie photos of the 1930s, 1960s and 1970s; a supposed Yeti footprint photographed in the Himalayas in 1951; the notorious film shot in California in 1967 said to depict a female Bigfoot walking alongside a creek; and tracks and other evidence also purported to belong to Bigfoot.

#### BOGUS BEASTS

Heuvelmans and his followers claimed that mainstream science displayed a disinterested, blinkered approach to these pieces of evidence, and to the study of mystery animals in general. In reality, qualified scientists investigated this evidence to a considerable degree, concluding that all of it could either be completely explained or labelled as significantly problematic. The photos that claimed to show Nessie all turned out to be hoaxes, or misinterpretations of waterbirds, waves, boat wakes or underwater objects like chunks of wood. Investigations ➤

BELOW: Bernard Heuvelmans' book, *On The Track Of Unknown Animals*, introduced the term 'cryptozoology' to the world



BELOW: This 1934 photo was considered evidence of the Loch Ness Monster. It turned out to be an elaborate hoax – the 'monster' was a toy submarine, with a head and neck made of putty



## GLOSSARY

### Bigfoot

A giant, hairy, man-shaped monster famous for leaving human-like footprints. Originally associated with California, cryptozoologists believe that it occurs across North America and even beyond.



### Cryptid

An animal argued by cryptozoologists to represent an unknown species or subspecies that has been described by witnesses but remains unconfirmed by science.



### Cryptozoology

The investigative field that aims to discover and study animals that are alleged to exist, but are as yet only known from anecdotal evidence.



### Mokele-Mbembe

An elephant-sized water monster of the Congo region, imagined by proponents to be a long-necked herbivore and perhaps a surviving sauropod dinosaur.



### Ropen

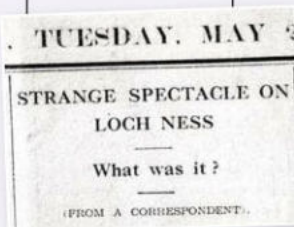
A giant, winged beast of New Guinea, said to be bioluminescent and to eat human corpses. Its proponents – most of whom are creationists – believe it to be a surviving pterosaur, a flying reptile otherwise thought to have died out 66 million years ago.



# TIMELINE: THE LOCH NESS MONSTER

Nessie has captured the public's imagination for over 80 years, ever since the first sighting in 1933

1933



**1933**

Mr and Mrs Spicer describe a large, blob shaped animal at Loch Ness, seen bounding across the road in front of their car. It triggers interest in the Loch Ness Monster.



**IVAN SANDERSON (1911-1973)**

This Scottish biologist worked with Bernard Heuvelmans to devise many ideas about cryptids. He travelled widely in pursuit of animals and wrote a lot of books.

**BERNARD HEUVELMANS (1916-2001)**

This scientist was the main proponent of cryptozoology. He wrote books and articles, and devised a number of ideas on the evolution of cryptids.



1967



**1967**

At Bluff Creek, California, Roger Patterson and Bob Gimlin film a large biped who matches Bigfoot descriptions. Debate rages over the film's authenticity.

**TIM DINSDALE (1924-1987)**

This aeronautical engineer achieved fame for his passionate interest in the Loch Ness Monster. He went in search of it on numerous occasions, with the intention of filming it.

1958

**1958**

Bernard Heuvelmans (pictured) publishes the English version of his book, *On The Track Of Unknown Animals*. It makes the case for Yetis and others as genuine animals.



1972

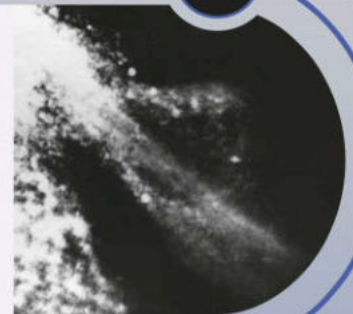


**MICHEL MEURGER (1946-)**

This folklorist argues that our ideas about monsters are continuations of folk stories. Creature sightings, he explains, are always interpreted within a 'cultural landscape'.

**1972**

Underwater photos taken at Loch Ness seemingly depict huge, diamond shaped flippers. Confidence in Nessie's existence is so high that two experts publish a scientific name for the beast: *Nessiteras rhombopteryx*.



1982



**1982**

The International Society of Cryptozoology is formed. It encourages an evidence led, sceptical approach to monster sightings, but also attracts weird, scientifically dubious claims. It folds in 1998 due to financial problems.

**ADRIAN SHINE (1949-)**

This scientist is a leading expert on Loch Ness, its history, ecology and biology, as well as being a noted sceptic. He has led numerous expeditions, including Operation Deepscan, and has tested many ideas about Nessie's existence.







RIGHT: Okapi weren't discovered until the 20th Century; some cryptozoologists think other large animals could be out there

published since 1999 show that the most famous Nessie photos variously depict a toy submarine, a blurry swan, a wave and an upturned kayak.

The alleged Yeti footprint of 1951 has irregular depressions at the left and right edges and heel, showing that it isn't a real primate track but a hoax manufactured by human hands. As for the 1967 Bigfoot film, an enormous amount of circumstantial evidence shows how Roger Patterson, the cameraman, planned for years to set up a hoaxed scene exactly like the one he filmed.

If photographic evidence has failed to pass the tests, what else might support the existence of monsters? An idea popular among cryptozoologists is that Nessie, Bigfoot and other mysterious beasts escape detection because they inhabit regions of the world that are remote and little explored. But is this true? Loch Ness is no remote Highland refuge, but has long been an important place for military campaigns, transportation and settlement. It's regularly traversed by ships, and became connected with other waterways in the 19th Century, ultimately forming the 97km-long Caledonian Canal.

Loch Ness also fails as the sort of place where giant, unknown animals could survive. It's home to waterbirds, fish of several species and small crustaceans. Otters frequent its surface, seals visit on occasion, and deer sometimes swim across it. But this is a scarce, low-diversity collection of creatures for a lake of this size and latitude. Indeed, the organic productivity of Loch Ness is so low that even the most optimistic calculations show that a population of large aquatic animals could not survive here, and certainly not for generations.

Similar arguments can be applied to other monsters. It's true that Bigfoot is associated with the wilds of British Columbia and Alaska, but what are we to make of the hundreds of reports from New York, Florida, and every other state across the US mainland? It would appear to be the commonest, most widely distributed non-human primate on the planet, occurring in places that cannot reasonably be regarded as potential haunts for a huge, as-yet-undiscovered mammal. Furthermore, it apparently lives right under the noses of hundreds of qualified biologists, conservationists and ecologists – any one of whom, make no mistake, would be rocketed to stardom (and, more importantly, tenure) if they proved the beast's existence.

Unlike Nessie, Bigfoot at least has some hard evidence put forward in support of it. But none of this has withstood scrutiny, and a long history of hoaxing and misinterpretation means that there's nothing convincing surrounding Bigfoot's existence. Even excellent 'gold standard' tracks have been shown to be faked. During the 1990s, anthropologist Grover Krantz argued that several plaster casts taken of Bigfoot tracks displayed marks made by the tiny ripples and grooves on primate feet, known as 'dermal ridges'. Similar marks were noticed on other tracks, and they were taken by proponents as powerful support for the reality of Bigfoot. However, in 2006, investigator Matt Crowley showed via a series of experiments that the marks were actually 'desiccation ridges'. These are formed in plaster as it sets: they are not proof of the biological reality of Bigfoot, but an accidental consequence of plaster casting.

## THE KEY EXPERIMENT

**Scientist:** Adrian Shine

**Date:** 1987

**Discovery:** No monster in Loch Ness

Given that Loch Ness is so large, the idea that rare, elusive animals might only be seen on the odd occasion when they break the surface seems reasonable. But this ignores the fact that the loch has been subjected to a surprising amount of close examination. At the height of monster fever during the 1960s and 70s, the loch's surface was observed perpetually for weeks at a time by banks of people armed with telescopes and binoculars. They failed to observe or record any compelling evidence for the monster.

Things were stepped up a notch in October 1987, when Nessie hunter and marine biologist Adrian Shine led 'Operation Deepscan' – at the time, the most extensive search of Loch Ness ever conducted. Over the course of two days, a flotilla of 24 boats equipped with echo sounders carried out a full length sonar sweep of the loch. On three occasions, contact was made with objects in deep water that couldn't be identified, nor relocated when investigated later. While unexplained and unlikely to represent fish, these 'contacts' were probably debris or thermal effects, or possibly even a seal. Indeed, nothing that can be interpreted with confidence as a giant animal has ever been encountered in any of the several sonar sweeps performed since.



ABOVE: Operation Deepscan was launched in 1987

BELOW: £1m of equipment was used in the hunt for Nessie







More recently, the claimed discovery of Bigfoot DNA has been used to support the ape's reality. A 2013 study claimed to have catalogued both mitochondrial and nuclear DNA from Bigfoot, showing that the beast is a hybrid between *Homo sapiens* and a second species of unknown ancestry. But independent checks by several geneticists revealed the results to be bogus, with the DNA found to be a mix belonging to various North American mammals.

### TALL TALES

Decades of investigation have shown that a significant percentage of classic monster

ABOVE: This photo was taken by mountaineer Eric Shipton during a 1951 expedition in the Himalayas. Some argue that the odd depressions suggest it was made by human hands, not Yeti feet

BELOW: Loch Ness isn't a productive body of water, so probably cannot support a large aquatic species

sightings can be explained as hoaxes or confused encounters with known animals or phenomena. What's more, virtually all photographic 'evidence' can be explained or dismissed, and ecological problems are attached to the supposed existence of various monsters. For all this naysaying, however, the fact remains that people continue to report sightings of these beasts. Why?

For years, folklorists and anthropologists have argued that modern ideas about monsters represent the vestiges of age-old folk beliefs in which dangerous places – deep lakes, dark forests, treacherous mountains – are associated with frightening creatures. The 'biology' and 'behaviour' of these animals is then reinforced by tales, anecdotes and artwork, passed down the generations. This explanation has increased in popularity since 1988, when folklorist Michel Meurger showed how people's ideas about lake monsters in northern Europe were linked to the

folklore of their culture. In other words, our cultures have primed us to imagine monsters whenever we see such things as dark shapes beneath the water, or shadows in a forest. The psychological term for this is 'perceptual expectancy'.

Psychology provides support for the idea that monsters are almost hardwired into our consciousness. Controlled experiments published since 2010 have shown how people 'see' monstrous apparitions, perceive frightening distortions of known objects, and have a distorted sense of size perception when they're afraid or confused, or while making observations in dim conditions.

So are we left with any compelling reason to think that massive, mysterious animals like Nessie and Bigfoot really exist? No, and despite extensive work and decades of searching, both monster proponents and sceptics have failed to produce any positive evidence that's even vaguely compelling. If there's any answer to the vexing question of why people claim to see the monsters, it's that we are all the products of those cultures to which we belong. We are complex, deluded creatures, typically refusing to abandon the fact that we're frequently tricked by our senses, our memories, and even our abilities to make sense of what we see. **f**

**Darren Naish** is a palaeontologist and science writer. His latest book is *Hunting Monsters: Cryptozoology And The Reality Behind The Myths*. Follow him on Twitter @TetZoo.

### DISCOVER MORE



Listen to an episode of *Witness* broadcast on the 25th anniversary of Operation Deepscan at [bbc.in/PLgjKB](http://bbc.in/PLgjKB)

**NEXT MONTH: UNDERSTAND THE END OF THE UNIVERSE**









# Are cities bad for our mental health?

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ACCORDING TO THE UN, ALMOST TWO-THIRDS OF US WILL LIVE IN CITIES BY 2050. THE GROWTH OF CITIES CANNOT BE STOPPED. NOR, IT SEEMS, DO WE WANT TO HALT THEIR EXPANSION. BUT SHOULD WE?

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**WORDS: BRENDAN KELLY**

Brendan is professor of psychiatry at Trinity College Dublin. His most recent book is *Mental Illness, Human Rights And The Law* (RCPsych Publications, 2016).

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# P

ersonally, I love cities. And I am not alone. In 1950, 746 million of us lived in urban areas. By 2014, that had increased to 3.9 billion, or 54 per cent of the world's population. According to the UN, 66 per cent of all humans will live in cities by 2050.

There is much that is good about cities. They are highly efficient ways of focusing human activities such as business, education and research. Managed correctly, they offer substantial environmental advantages. Cities bring us into closer routine contact with other humans, and most of us seem hardwired to seek out this enhanced level of contact: we like being in cities as much as we like being around people. But while we like cities, do our bodies and brains like them too?

Our beloved cities are associated with increased rates of childhood asthma, heart disease, diabetes and various cancers, as well as childhood psychiatric illnesses, adult depression and even schizophrenia. Research into these disturbing

statistics is best explored by looking at schizophrenia – surely the most enduring and mysterious malady in the history of medicine.

#### WHAT IS SCHIZOPHRENIA?

Schizophrenia affects approximately 1 per cent of the world's population at some point in life. Its causes are unknown, and it is more common in men than women.

Symptoms start with subtle changes in childhood thinking and behaviour, but these are so vague that they are only recognisable in retrospect or in research studies. The vast majority of such children do not develop

psychological or psychiatric problems. Nonetheless, these subtle changes indicate that, for many people with schizophrenia, brain development takes a different pathway from an early stage, possibly even while still in the womb.

The first noticeable symptoms of schizophrenia emerge in the teenage years and include anxiety, low mood, social withdrawal or a preoccupation with odd beliefs. These symptoms are felt by most teenagers (and many adults) at some point, so do not necessarily mean that the person is mentally ill. However, if they are present to a substantial extent they might identify a young adult who is at high risk of psychological or psychiatric problems.

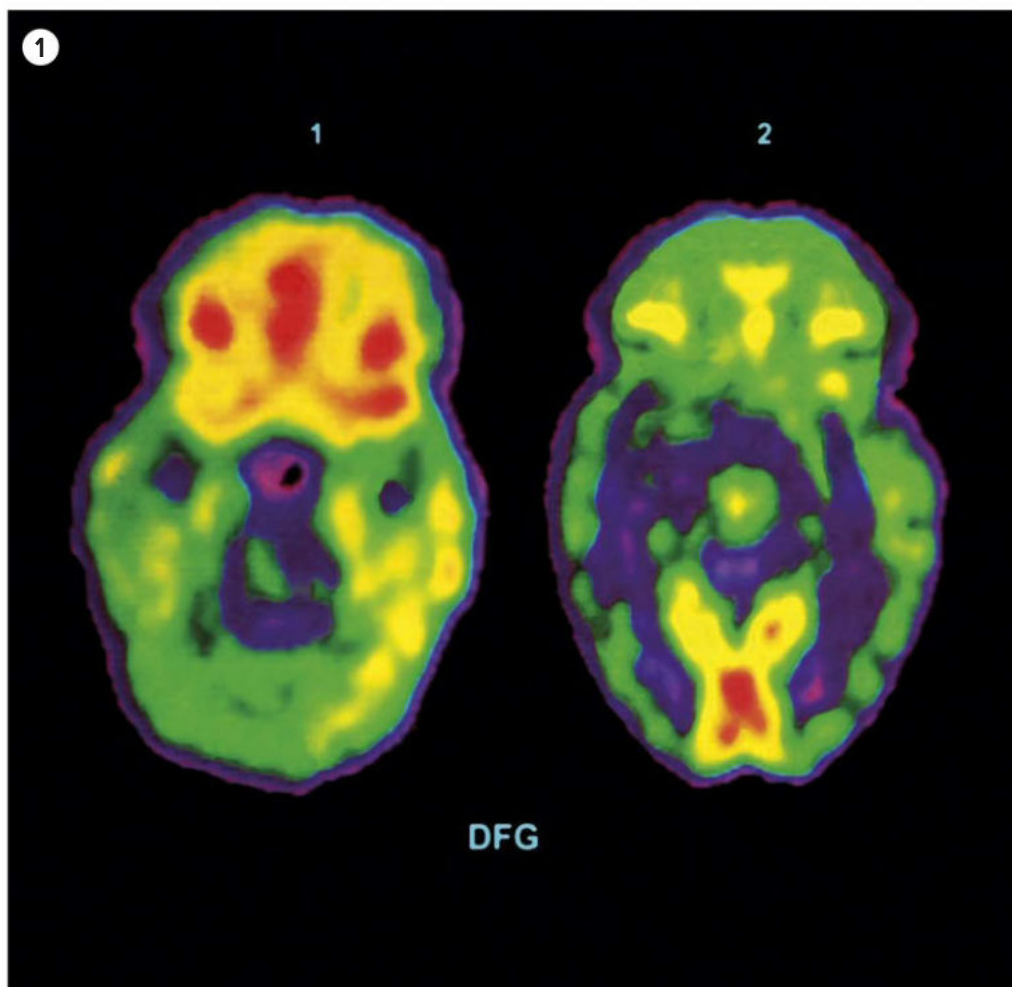
The classical symptoms of schizophrenia, when they eventually emerge, include delusions and hallucinations. Other features include difficulties with clear thinking and a range of 'negative' symptoms similar to depression: low mood, loss of interest, depleted energy and persistent social withdrawal.

#### MEDICAL MYSTERY

While there has been much research into the biological underpinnings of schizophrenia, the disorder still remains one of the true enigmas of medicine. This is partly because 'schizophrenia' is really a term used to denote a cluster of symptoms which tend to occur together, rather than a biologically defined entity. This places schizophrenia in sharp contrast to conditions such as diabetes, which is biologically defined by measurement of blood glucose, or brain tumours, which are diagnosed with brain scans. There are no blood tests or brain scans for definitively diagnosing schizophrenia. Nonetheless, there is growing evidence that dopamine, a key neurotransmitter in the brain, is abnormally regulated in schizophrenia. Given the highly interconnected nature of the brain, other neurotransmitters are sure to be involved too. ●

**In 1950, 746 million of us lived in urban areas. By 2014, that had increased to 3.9 billion – 54 per cent of the population**

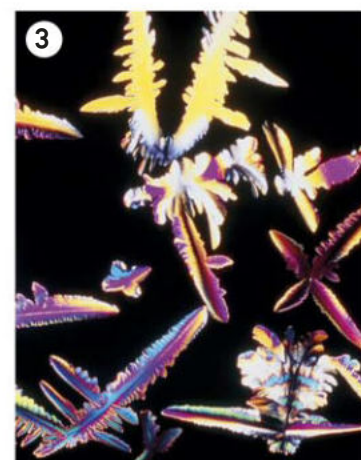




1 A scan of a healthy brain (left) compared to a schizophrenic brain (right) during an attention test. Red shows high activity, through yellow, green and black (low activity)

2 Young people born in a city environment have an increased risk of developing conditions such as schizophrenia. One factor that could contribute towards this is a higher baseline cortisol level in the body

3 Cortisol is produced by the adrenal gland in response to stressful situations







Cities offer an efficient way to carry out our lives, but they can put our health at risk

PHOTO: GETTY



● There is also a strong genetic element to schizophrenia, and there are likely to be multiple genes of moderate or small effect, which have yet to be fully understood. Moreover, it remains stubbornly the case that most people with schizophrenia do not have a family history of the disorder, and most people with a family history do not develop schizophrenia. Therefore, while family history and genes increase the risk of schizophrenia, environmental factors are critically important too. And this – finally – brings us to cities.

### **SCHIZOPHRENIA IN THE CITY**

Studies of the distribution of schizophrenia around the world have long recognised that the condition is more prevalent in urban areas than rural ones.

Research that took place back in the 1960s and 1970s showed that the most obvious explanation for this turns out to be at least partly true: people who have pre-existing schizophrenia tend to move to urban areas to seek out assistance, accommodation and support, leading to a relative concentration of schizophrenia in cities as a result of the disorder.

It soon transpired, however, that this ‘urban drift’ effect was not of sufficient magnitude to entirely explain the association between schizophrenia and cities. Various other factors were at play. Studies from the 1970s onwards shed further light by demonstrating repeatedly that, even after taking ‘urban drift’ into account, cities are associated with a substantially increased risk of people developing schizophrenia. The more methodologically sound and larger the study, the greater the risk associated with cities.

All told, the scientific literature now definitively shows that urban birth, urban upbringing, and urban living are all associated with an increased risk of subsequent schizophrenia.

Just like having a family history of schizophrenia, exposure to urban environments appears neither necessary nor sufficient for developing the disorder, but it does increase the lifetime risk from 1 per cent to approximately 2 per cent, using the best available estimates. This increase in risk is not nearly enough to advise against living in a city, even among those who have a family history or

other risk factors for schizophrenia. So don’t move house – at least not yet.

But the fact that such a small risk is identified so consistently by different research groups, using different methodologies, in different locations, at different times, makes it unlikely that the finding is due to chance alone. Moreover, in terms of causality, there is not only a strong correlation between cities and schizophrenia, but there is also evidence of a dose-response effect: the greater the degree of urbanicity at birth, the greater the risk of developing schizophrenia.

There is clearly something at work here, some unidentified biological or psychological factor associated with cities that alters brain development or function to increase the risk of schizophrenia. But what is it?

### **SEARCHING FOR THE SOURCE**

There are multiple suggested explanations for the link between cities and schizophrenia. For example, there is long-standing evidence that if a mother becomes unwell during pregnancy, such as coming down with influenza, then it might increase the baby’s risk of developing an illness or disorder as a young adult.

Another theory is that cities are associated with increased exposure to cats and, therefore, the risk of cat-borne infections such as toxoplasmosis. It now appears that if there is an association between cats and schizophrenia (and that is not yet proven), it is independent of the link between cities and schizophrenia. Other possible explanations for higher levels of schizophrenia in cities include increased exposure to air pollution and more incidences of vitamin D deficiency. But these, too, remain unproven.

As interest in this field soared during the 1990s, several possible explanations were ruled out. It is now clear that the increase in risk is not closely linked with socioeconomic group in childhood, household overcrowding, parental lower income, parental unemployment, increased cannabis use, or number of older siblings. So what theories are left?

Some of the most compelling schizophrenia research in recent years links increased risk of the disorder with ‘community disorganisation’ and its associated social, psychological and biological effects. For example, it is known that migrants experience increased rates of many mental disorders, including schizophrenia. Why? Psychiatrist Dr Jane Boydell and colleagues have shown that the smaller an ethnic minority group is, the greater its increase in risk. In other words, the size of any ethnic minority group operates as a buffer against the increased risk of schizophrenia: the larger the group, the lower the risk. Are these social risk factors having a greater impact in cities ●

**Urban birth, urban upbringing, and urban living are associated with an increased risk of subsequent schizophrenia**



A combination of factors contribute towards higher schizophrenia levels in city environments



### How many people live in cities?



**1950**  
746 million people living in cities  
World population: 2.5 billion  
**29%**



**2014**  
3.9 billion people living in cities  
World population: 7.2 billion  
**54%**



**2050**  
6.4 billion people will live in cities  
Projected world population: 9.6 billion  
**66%**



• than elsewhere, accounting for the link between urban living and schizophrenia? And, if so, what is the reason for this effect?

### STRESS AND SOCIAL FRAGMENTATION

Many psychiatric disorders, including schizophrenia, are associated with disturbances of the body's stress responses. This is reflected in levels of cortisol, which is a steroid hormone that's produced by the adrenal gland in stressful situations. Chronic production of high levels of cortisol has a damaging effect on virtually all body systems, including the brain. It is possible, and even probable, that belonging to a small migrant group is associated with a state of chronic stress, producing increased baseline cortisol and therefore increased risk of schizophrenia.

There are reasons to believe that this kind of 'stress effect' is more powerful in urban areas, because city living affects the brain's response to stress. Baseline levels of crime, social fragmentation and urban decay are also important. This model, linking community factors with effects on individual brains, receives strong support in a study by Duke University and King's College London, published in *Schizophrenia Bulletin* in May this year. The team analysed data from over 2,000 UK-born twins and found that reduced social cohesion and crime victimisation likely explain, at least in part, why children in cities have an increased risk of developing symptoms of disorders such as schizophrenia. It is not the cities themselves,

then, but the way we live in them that likely matters most.

This is an exciting finding that is both consistent with previous studies and robust enough to add extra weight to the idea that community disorganisation is closely linked with whatever mysterious biological mechanism connects cities with schizophrenia. So while research is clearly heading in the right direction, it still remains unclear what any of this will mean for the treatment and prevention of schizophrenia.

**Chronic production of high levels of cortisol has a damaging effect on virtually all body systems, including the brain**

### WHAT NEXT?

There are many pharmaceutical, psychological and social treatments for schizophrenia, and these help patients and families a great deal. It is critical that these treatments are delivered efficiently, effectively and with compassion, to heal and empower the mentally ill and their families. But these treatments are deeply imperfect and are not cures for schizophrenia. The prospects of better treatment would be much improved if we understood precisely what causes schizophrenia in the first place. But we do not.

In the search for answers, it is critical to develop a better understanding of urbanicity and – even more so – its relationship with other risk factors, such as genes, prenatal or birth injury, psychological trauma, cannabis, head injury, migration, social adversity, chronic stress and others. All are of these linked with schizophrenia to varying degrees, but none are fully understood.

Ultimately, research is hampered by the fact that schizophrenia is defined by symptoms rather than biological tests. 'Schizophrenia', like 'fever' or 'headaches', is almost certainly an umbrella term that covers a family of different but related 'sub-disorders', rather than a single, biologically distinct entity. These sub-disorders, despite sharing many symptoms, might well have somewhat different origins in different groups or individuals.

As a result, schizophrenia retains the ultimate mystery that is intrinsic to all true scientific enigmas: it might not exist as a definable entity. The undeniable suffering of people diagnosed with schizophrenia may well reflect different combinations of risk factors producing similar – but not identical – collections of symptoms.

In this context, the link between schizophrenia and cities is, perhaps, not so surprising. Cities are complex, intricate entities, difficult to define, challenging to explain, and yet remarkably enduring throughout recent human history. Cities, in other words, are a lot like schizophrenia. •

### DISCOVER MORE



To find out more about schizophrenia and other mental illnesses, visit [rethink.org](https://rethink.org)



What do you think? Have your say on our Twitter page [@sciencefocus](https://twitter.com/sciencefocus), or email [reply@sciencefocus.com](mailto:reply@sciencefocus.com)




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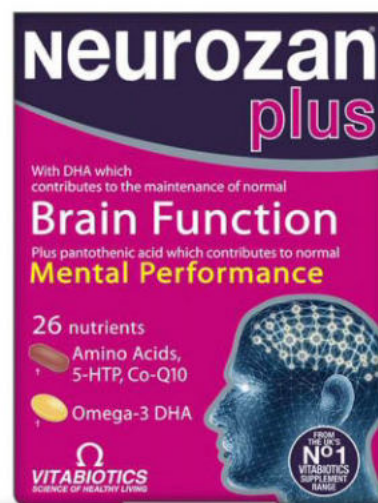
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## ROBERT MATTHEWS ON... **THE EMISSIONS SCANDAL**

**“NITROGEN OXIDES ARE RESPONSIBLE FOR AN ESTIMATED 23,000 DEATHS IN THE UK EACH YEAR”**

**S**

ome of life's problems are easily solved. How do we deter people from cheating?

Simple: keep an eye on them, and hand out punishment when they transgress.

This time last year, the US Environmental Protection Agency (EPA) made headlines when it applied this strategy to Volkswagen. The EPA revealed that for years VW had been secretly fitting its cars with software that detected when a car was undergoing a test, and tweaked the operation of the engine, temporarily reducing performance – along with its emissions. Once the car was on the road, the software brought the performance back up – together with the levels of noxious oxides of nitrogen (NOx), which soared above the official standard. A year on, and VW has confessed, lost its CEO and agreed to pay billions in compensation.

But there's a bigger scandal lying behind the story, one that shows what can happen when politicians reach for simple solutions to problems that are anything but. Just a few days before the EPA revealed its findings, the UK government announced plans to improve air quality. Its consultation document focused on NOx, stating that “it is well-established” that they have an impact on health. But a technical appendix went further, putting a figure on that impact. It was – in every sense – breathtaking: NOx are responsible for an estimated 23,000 deaths in the UK each year. That is a staggering figure – well over 10 times the UK's annual death toll from road accidents.

You might think figures like that would make headlines. In fact, they were barely covered. It didn't help that the press release was put out on a Saturday, and on the weekend when the Labour Party was electing a new leader. Conspiracy theorists seize on such details. But you don't need to be wearing a tinfoil hat to suspect ministers



might want to ensure the death toll estimate gets minimal coverage.

That's because among the most potent sources of NOx are diesel engines, which governments have been promoting in their fight against global warming. As they're more efficient than petrol engines, diesel engines produce less carbon dioxide – the most notorious greenhouse gas. In reality, most of that benefit is lost because diesel cars are typically bigger and heavier. Plus, diesel engines are far more potent sources of NOx

and smoke-like particulate pollution. According to the document, the two combined cause over 50,000 deaths in the UK each year.

This has been known for years. Yet politicians in the UK and across Europe have been deaf to the warnings. They have stubbornly clung to the idea that diesel engines are a simple remedy in the fight against global warming. They have even offered tax breaks to promote their use, while insisting that pollution is being tackled via tight emission standards. It's now known that even before the EPA's announcement, officials in Europe were told the tests

were being gamed by manufacturers. Nothing was done. The tinfoil hat brigade will no doubt have their explanations for that, too. But we should all be asking why governments continue to tolerate thousands of deaths right now in return for mythical protection from a threat decades in the future.

If you'd like to share your views on this column or anything else in the magazine, email [reply@sciencefocus.com](mailto:reply@sciencefocus.com)

**Robert Matthews** is visiting professor in science at Aston University, Birmingham.

### DISCOVER MORE



Watch an episode of *Panorama* about the Volkswagen emissions scandal at [bit.ly/VW\\_emissions](http://bit.ly/VW_emissions)  
**NEXT ISSUE: IS BIG SCIENCE DEAD?**





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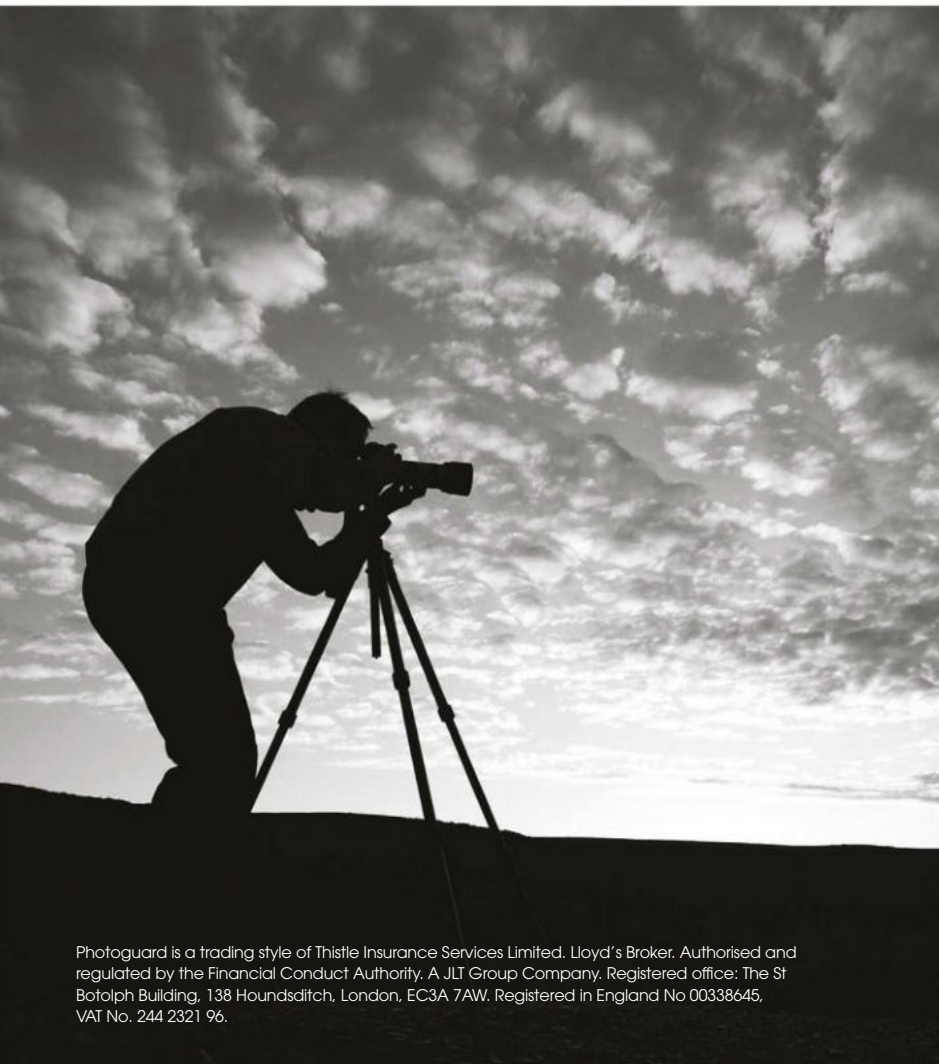
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**DR CHRISTIAN JARRETT**  
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**DR ALASTAIR GUNN**  
Alastair is an astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester.



**PROF ROBERT MATTHEWS**  
Robert is a physicist and science writer. He's visiting professor in science at Aston University.



**DR PETER J BENTLEY**  
Peter is a computer scientist and author who is based at University College London. His latest book is *Digitized*.



**LUIS VILLAZON**  
Luis is a freelance science and tech writer with a BSc in computing and an MSc in zoology from Oxford University.



**PROF MARK LORCH**  
Chemist and writer Mark is a professor at Hull University. He recently co-edited *A Flash Of Light*.

# YOUR QUESTIONS ANSWERED

SEPTEMBER 2016

EDITED BY EMMA BAYLEY



## How long until we run out of landfill space?

CAROLINE SMITH, LONDON

In the UK, estimates typically range from six to eight years. But local authorities have been saying this since at least 2010 and we aren't there yet. This is because EU directives have steadily increased the landfill tax, so councils have been driven to recycle more and more of their waste. In 2009, 90 per cent of our rubbish went to landfill. It's less than 50 per cent now and forecast to drop to 10 per cent by 2020. **LV**

In 2015, the Lebanese government closed the only landfill site in Beirut without putting an alternative in place. Huge piles of rubbish started building up in the city

PHOTO: GETTY





## What causes muscle twitching?

OLIVIA MACK, NEWICK

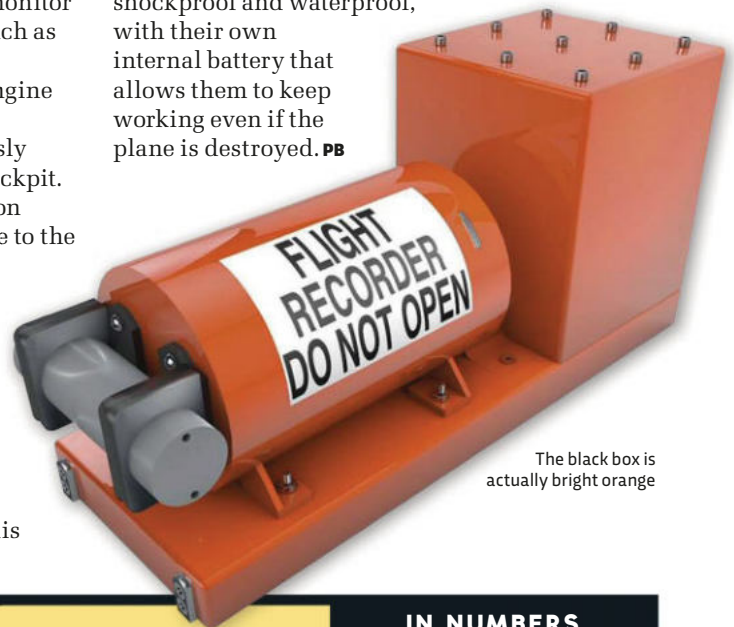
That random little twitch that you sometimes get in your eyelid is an example of fasciculation. It happens when one of the lower motor neurons in your spine spontaneously fires a signal. These nerves control an entire block of muscle fibres, so they all contract at once. Because it's benign, there hasn't been much research into the causes, but magnesium deficiency is thought to be one factor. **LV**

## Why can't black box information be stored in the Cloud?

BYRON WILLIAMS, WALES

Modern flight recorders store up to 25 hours of data in a continuous loop. They monitor at least 88 parameters such as cockpit control settings, information about the engine and the time. The voice recorder also continuously records sounds in the cockpit. While all this information could be transmitted live to the Cloud, there is no guarantee that this will always work, especially during those critical seconds of a disaster. Wireless transmissions are also susceptible to electrical storm interference, jamming or fraud. For this

reason, black boxes are self-contained, fireproof, shockproof and waterproof, with their own internal battery that allows them to keep working even if the plane is destroyed. **PB**



The black box is actually bright orange

### WHAT'S IN...

## ...CHEWING GUM

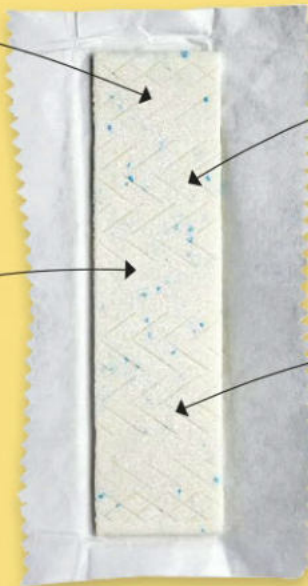
Chewing gum is basically plastic doped with flavours and colourings. It is non-digestible and water insoluble, which means you can carry on gnashing away at the stuff and it never seems to break down. This indestructible property comes from the gum base, the exact ingredients of which are usually a trade secret. However they generally contain:

#### FILLERS

Calcium carbonate or magnesium silicate (talc) provide texture and bulk. If the gum has acidic flavours, then talc is used. This is because calcium carbonate would react and produce carbon dioxide gas.

#### ELASTOMERS

These are long polymer molecules with elastic properties. Until WWII, chewing gums used a natural latex derived from sapodilla trees, but since then synthetic elastomers, such as polyvinyl acetate, are preferred.



#### EMULSIFIERS

These help to keep other ingredients, including flavours and colourings, nicely mixed and also impart some anti-stick properties.

#### SOFTENERS

Compounds such as vegetable oil and lecithin are added to the gum base to keep everything soft and chewy. Masticate for too long and these can get washed away, leaving you with an overly stiff piece of gum.

### IN NUMBERS

**54**  
per cent

The percentage of UK men who will develop cancer. For women, the figure is 48 per cent.

**18**

The number of carnivorous caterpillar species in Hawaii.

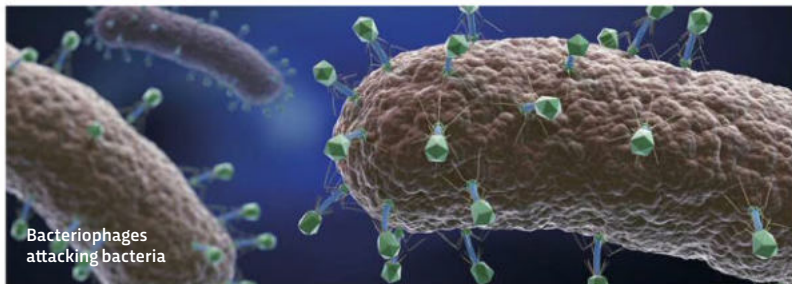
**100**

The approximate number of Scottish wildcats remaining in the wild.



## Can a bacterium be infected by a virus?

KARL LEWIS, MALTA



Yes. These viruses are called bacteriophages and they are extremely common. Around a quarter of the bacteria in the sea at any one time are infected by bacteriophages and they are so successful that the viruses often outnumber bacteria by a factor of 10. Bacteriophages have a strand or loop of DNA enclosed in a special protein sheath that acts like a hypodermic syringe. One end binds to proteins on the

bacterial cell membrane and this causes the sheath to contract, puncturing the membrane and injecting the DNA. The virus's genes are then automatically transcribed by the bacterium's own cellular machinery, which builds hundreds of copies of the virus. After about 20 minutes the bacterium is so full of new viruses that it bursts open, releasing the viruses to infect other cells. **LV**



## How do we know when a rock is from space?

SUSIE HAYNES, LIVERPOOL

The first thing you'll need is a magnet. Almost all meteorites are rich in iron so they'll stick to magnets. But there are plenty of terrestrial stones that will pass this test too. Next, you'll need to see if the rock's surface looks like it burnt or melted as it passed through the atmosphere: does it have a burnt black crust or flow lines where rivulets of molten rock ran over the surface? If everything checks out so far, then you'll have to get a lab to test for nickel content. Virtually all meteorites contain significant amounts of nickel, which is an element that is fairly rare on Earth. **ML**

### THE THOUGHT EXPERIMENT

## HOW CAN I SURVIVE A BEAR ATTACK?



### 1. DON'T RUN

Black, brown and polar bears can all outrun you, and fleeing will trigger the bear's predatory instincts that make an attack more likely. Climbing a tree might help against a brown bear, but black bears are excellent climbers. Standing your ground or backing away slowly are better tactics, even if the bear is charging.



### 2. DON'T SHOOT

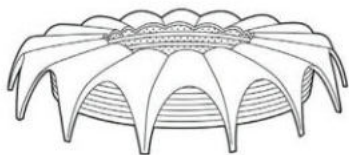
A bullet won't kill a charging bear before it reaches you. Pepper spray is more effective. The idea is to spray a wall of mist between you and the bear, while the bear is still 10 to 15m away. This doesn't require accurate aim and will often deter the bear instead of just enraging it.



### 3. DON'T PANIC

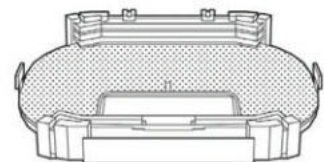
Black bears can sometimes be fought off, especially if you hit their nose or eyes. With brown bears the best tactic is to play dead. Keep your rucksack on, interlock your fingers around the back of your neck and curl up tight on the floor. Stay there for at least half an hour. The bear will often wait to see if you are really dead.

# LARGEST STADIUMS



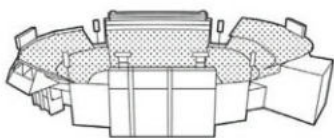
## 1. Rungrado 1st of May Stadium

Seating capacity: 150,000  
Location: Pyongyang, North Korea



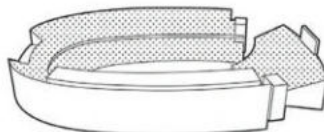
## 2. Michigan Stadium

Seating capacity: 107,601  
Location: Ann Arbor, Michigan, USA



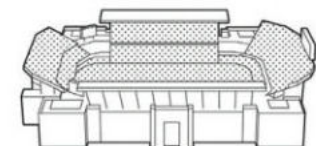
## 3. Beaver Stadium

Seating capacity: 106,572  
Location: University Park, Pennsylvania, USA



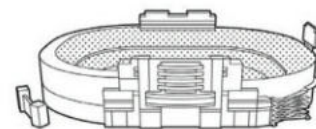
## 4. Ohio Stadium

Seating capacity: 104,944  
Location: Columbus, Ohio, USA



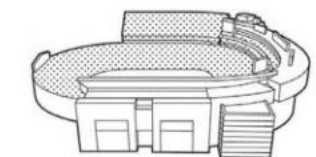
## 5. Kyle Field

Seating capacity: 102,733  
Location: College Station, Texas, USA



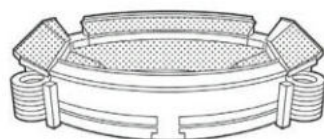
## 6. Neyland Stadium

Seating capacity: 102,455  
Location: Knoxville, Tennessee, USA



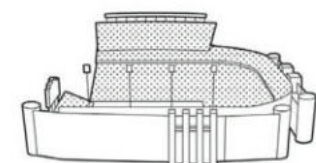
## 7. Tiger Stadium

Seating capacity: 102,321  
Location: Baton Rouge, Louisiana, USA



## 8. Bryant-Denny Stadium

Seating capacity: 101,821  
Location: Tuscaloosa, Alabama, USA



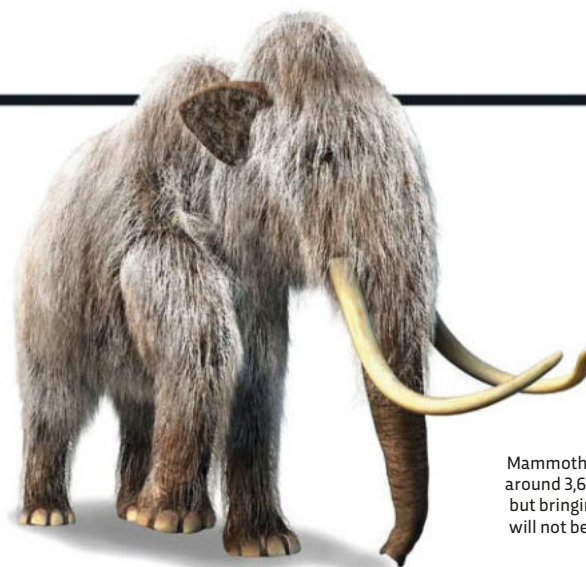
## 9. Darrell K Royal-Texas Memorial Stadium

Seating capacity: 100,119  
Location: Austin, Texas, USA



## 10. Melbourne Cricket Ground

Seating capacity: 100,024  
Location: Melbourne, Australia



Mammoths still existed around 3,650 years ago, but bringing them back will not be an easy task

## Could we clone a mammoth or a dinosaur?

NATHAN ALLISON, YORKSHIRE

The oldest DNA fragments recovered are only 800,000 years old, so dinosaur cloning is probably impossible. True cloning also requires an intact, living cell and it has only ever been successful using a host animal of the same species. That rules out mammoth cloning too.

What we might be able to do is splice some mammoth genes into the DNA of the Asian elephant, their closest relative. Most of the mammoth genome has already been sequenced from fragments recovered from mammoths frozen in the Siberian permafrost. Last year, a team at Harvard managed to insert 14 mammoth genes into an elephant cell in a petri dish. But Asian elephants and mammoths are thought to differ by at least 400 genes, and figuring out exactly which ones are different will take a while. And then that single cell still needs to develop into an embryo and then a baby mammoth. We don't know enough about elephant reproduction to even manage ordinary in vitro fertilisation (IVF) yet, and the success rate of implanted cloned cells is so low that it would be impractical and unethical to try this with elephant surrogate mothers. We may be able to make progressively more mammoth-like elephant hybrids, but it will be a slow process. **LV**

## How are we able to drink scalding drinks, like tea?

DENNIS TAYLOR, NEWQUAY

When you tackle a really hot cup of tea, you will typically start with a noisy sip. This takes a very small amount of liquid into your mouth, mixed with a lot of air. The total thermal energy in the small volume is low and it is distributed over a wide area in your mouth. Each square centimetre doesn't receive enough heat to burn the skin. **LV**





# How do we get superhuman strength in a crisis?

MARK WELLS, LITTLEHAMPTON

Physiologists used to think that the muscles controlled their own effort levels, shutting down when exhausted. We now know that the brain plays a much bigger part, and that fatigue signals from the muscles are weighed in the context of motivation, beliefs and expectations. When we're in a life-threatening and adrenaline-fuelled situation, it makes sense that the brain abandons its usual conservative approach and instructs the muscles to work much nearer their full capacity. But also bear in mind that many anecdotes about superhuman strength are not as incredible as they first seem. For example, it's usually one corner of a car's bulk that is briefly lifted, not its full weight. **q**



Luckily, we don't tend to turn green when we gain superhuman strength

## QUESTION OF THE MONTH

### How fast would Earth need to spin for humans to be thrown into space?

DAISY CLARE, AGE 10, SWINDON

Normally, humans aren't thrown off the moving Earth because gravity is holding us down. However, because we are rotating with the Earth, a 'centrifugal force' pushes us outwards from the centre of the planet. If this centrifugal force were bigger than the force of gravity, then we would be thrown into space.

The strength of the centrifugal force depends on where you are. It is greatest at the equator and zero at the Earth's poles. We can calculate how fast the Earth would need to spin to balance the force of gravity (this is known as the 'escape velocity'). It works out at about 28,437km/h (17,670mph). The Earth would have to spin once every 84 minutes to achieve that speed at the equator, or about 17 times faster than it actually

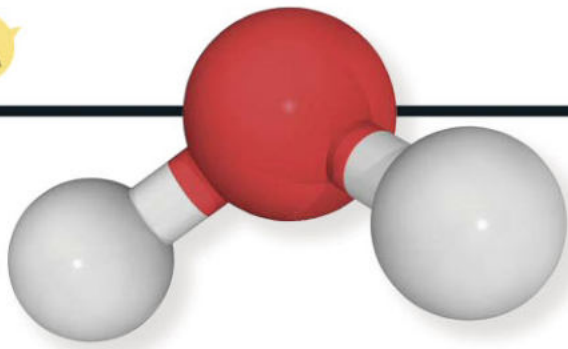
spins. If you move away from the equator the centrifugal force is lower so you still wouldn't fly off into space, even at that speed. At the latitude of Swindon, for example, the Earth would need to rotate once every 52 minutes to throw the resident humans off into space. **ac**

#### WINNER!

Daisy Clare wins a fantastic LEGO City Volcano Exploration Base (£79.99, [lego.com/city](http://lego.com/city))\*. This exciting set follows the exploits of a team of scientists as they study an erupting volcano.







Water's strange properties are all down to its molecular charges

## Why is water so strange?

MATT BARKER, ST ALBANS

Water has many strange properties, including a high surface tension, an ability to dissolve more things than any other common liquid, and a solid state (ice) that floats. These strange properties come from water's simple structure. Its atoms form a chevron shape with a slightly negatively charged oxygen and positive hydrogens. This allows water to bind to and dissolve both negatively and positively charged molecules.

Meanwhile, the hydrogen of one water molecule is attracted to the oxygen of another. Within a liquid these attractions briefly hold the molecules together, generating the high surface tension. This network is frozen in place when the water is cooled, leaving large gaps. As a result, the sponge-like ice floats on the liquid. In contrast, other chemicals form tightly packed solid crystals that are more dense than the liquid and so sink. **ML**

## What is the biggest telescope on Earth?

ISABELLE SANDERS, LONDON

The world's largest radio telescope should be fully operational in September this year. FAST, as the 500m-wide telescope is called, is located in Pingtang County in southwest China. The image to the right was taken inside the reflector of the telescope. A total of 4,450 panels make up the reflector, and suspended in the middle is the cabin, which will collect signals from space. FAST will gather data on pulsars, galaxies, black holes and signs of extraterrestrial life.

The biggest optical telescope in operation is the Gran Telescopio Canarias (GTC), with an aperture of 10.4 metres. There are larger optical telescopes in the pipeline though.

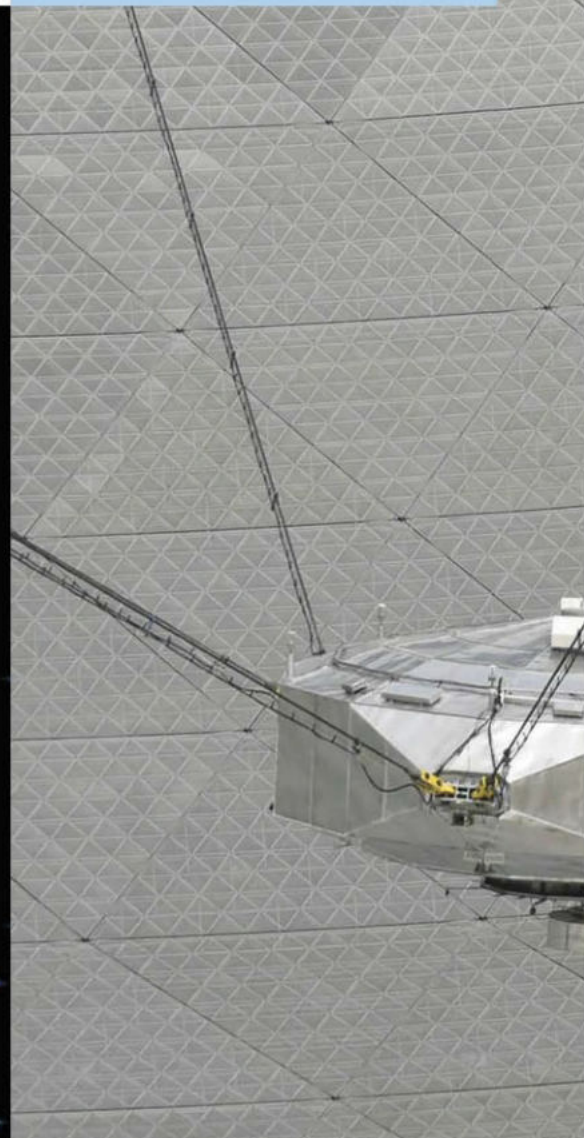
### NO EASY ANSWER

## HOW DID THE MOON FORM?

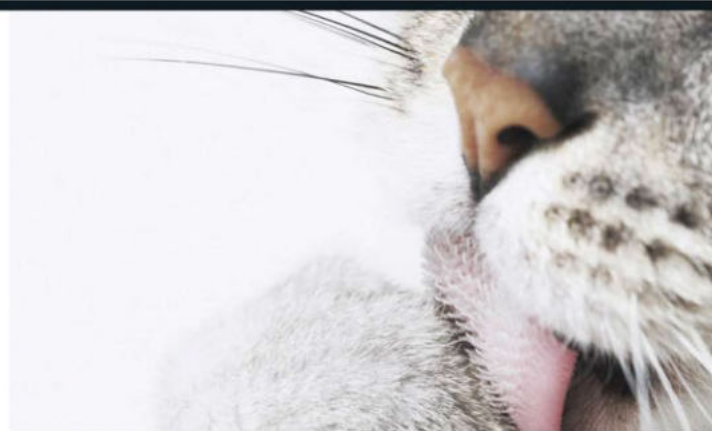
One possibility is that the Moon was originally an independent dwarf planet that was captured by Earth's gravity. Mars is thought to have snagged its two moons, Phobos and Deimos, this way.

Alternatively, the Moon and Earth could have formed together, from the same dust and gas. This is more consistent with the Moon's orbit but it doesn't explain why it is much less dense than Earth.

But the theory currently preferred by astronomers is that a Mars-sized planet, called Theia, collided with Earth 4.5 billion years ago. The Moon was formed from the lighter crustal elements that were blasted into space by the impact, leaving Earth's denser core behind.







## Why do cats have rough tongues but dogs don't?

ELLA WARD, MANCHESTER

Cats have hard, backwards-facing spines on their tongues, called filiform papillae. These work like a comb for grooming their fur, and are also used to rasp meat from animal bones. Cats are solitary hunters, but are also small enough to be

prey for other animals, so grooming is important to minimise their own scent and make them harder to detect. Dogs evolved from pack-hunting wolves and grooming isn't so important, so they have ordinary, smooth tongues. **LV**

## How can something explode in the vacuum of space?

CLAYTON CAUDWELL, LINCOLN



Many astronomical objects such as novae, supernovae and black hole mergers are known to catastrophically 'explode'. This means that they energetically destroy themselves or fundamentally change, releasing matter and energy into the Universe. These are quite different from many explosions here on Earth, which, apart from being feeble in comparison, usually require oxygen or an added oxidant in order to 'burn'. But as long as the explosion doesn't require oxygen, then it will work in much the same way in space as on Earth. **AG**

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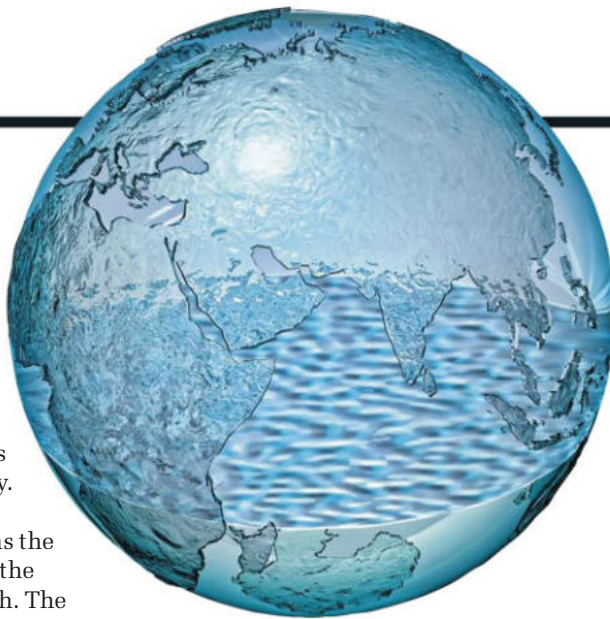




## Is a liquid planet possible?

HARVEY TURNER, JERSEY

It is probably not possible for a planet to be entirely liquid. This is because a planet needs to be 'self-gravitating' so that it holds its spherical shape under gravity. It thus requires a substantial amount of mass, which means the pressure and temperature in the inner regions are usually high. The difference between the interior and exterior means that matter cannot exist in a single state, and there will always be regions where the material is vapour or



solid. However, it is possible for a planet to be entirely covered by liquid over a solid core. **AG**

## Why aren't virtual humans totally realistic?

CLIVE BOAKES, DERBY



Realism is all about our preconceptions. When simulated organisms look like cartoons, we accept them. As they look more real, we think they're a bit freaky – like zombies – because their artificial intelligence and range of movements are not good enough to make them behave naturally. This dip in our acceptance as realism improves is called 'the uncanny valley' in research – or as I like to call it, 'the freaky effect'. You need a clever brain to move and behave appropriately, and our AIs are still too simple to cope. One day, if we could make them clever enough to be indistinguishable from real, then we might truly accept them. **PB**

### WHAT CONNECTS...

#### ...BACTERIA AND BOMBS?

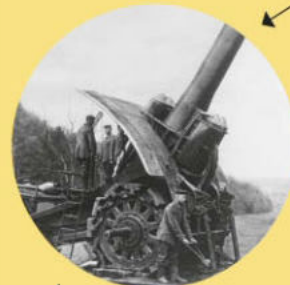


# 1.

All living things need nitrogen to make protein, but before the nitrogen in the air can be metabolised, it must first be converted into ammonia by certain bacteria.

# 2.

These bacteria are essential because they can make the nitrogenase enzymes that catalyse the nitrogen conversion. Each nitrogenase molecule contains a single atom of the element molybdenum at its core.



# 3.

Molybdenum can also be added to steel to make very hard alloys. The WWI 'Big Bertha' howitzers were one of the earliest uses of molybdenum steel.



# 4.

Big Berthas fired shells that weighed nearly a tonne. The explosive was trinitrotoluene, or TNT, which is made by reacting nitric acid and toluene. Nitric acid is made from ammonia.



## WHAT IS THIS?

### Shoot for the stars

This is a prototype 13kW plasma based Hall thruster that was tested by NASA earlier this year. It will be used to develop an advanced solar electric propulsion system, which will eventually allow us to explore deep space, asteroids and Mars.

Manufacturer Aerojet Rocketdyne has been awarded the three year, \$67m contract to develop the system.

## WHO REALLY INVENTED?

## VACCINATIONS

MARY  
WORTLEY  
MONTAGUDR  
EDWARD  
JENNER

In 1796, Gloucestershire physician Dr Edward Jenner conducted one of the most important – if unethical – experiments in medical history. His aim was to investigate claims that people could be protected from deadly smallpox if previously exposed to cowpox, an apparently related but harmless disease. To find out, he risked the life of an eight-year-old boy (whom he had exposed to cowpox) by deliberately exposing him to smallpox. Apart from a brief fever following the cowpox infection, the boy remained healthy. Ever since, Jenner has been hailed as the discoverer of ‘vaccination’, a vital weapon in the fight against disease and one that led to the global elimination of smallpox in 1980.

The idea that prior infection gave ‘immunity’ against later disease had, however, been noted as early as the 10th Century by Chinese physicians. By the early 18th Century, Lady Mary Wortley Montagu, wife of a diplomat in Turkey, was advocating ‘variolation’. This involved deliberately exposing patients to smallpox-infected tissue. While often successful, the technique was risky, with around one in eight dying from smallpox.

Jenner was not even the first person to test cowpox as a way to provide immunity against smallpox. Even so, he deserves credit for studying the theory systematically, and convincing the Royal Society to publish his findings.

# Why hasn't intelligent alien life found us?

RAY PRAVEL, READING



Sceptics have a simple answer: intelligent aliens have not contacted us because they don't exist. But others argue that, given the enormous size of the Universe, it's pretty much guaranteed that intelligent life must be out there somewhere.

Maybe so, but there's no guarantee it exists nearby, or has learned of our existence through the ‘leakage’ of our TV and radio signals into space. So unless

they've found a way of travelling far faster than the speed of light, we might be in for a long wait until they get here. Another explanation for what's been called the Great Silence is that as soon as aliens attempt to make themselves known to others, they are attacked by a race of marauding ETs. Alternatively, perhaps they're already here and we're just too stupid to realise. **RM**

# Why are so many people allergic to peanuts?

HELEN SHIPLEY, DURHAM

Nobody is exactly sure, but it seems to be a combination of factors. Higher hygiene levels in modern society may cause the immune system to develop inappropriate reactions to some food proteins, and the

fact that peanut oil is used in a lot of infant skin creams may prime the immune system early on. Roasting peanuts also seems to increase the concentration of some of the allergens. **LV**



PHOTOS: GETTY X3, ISTOCK

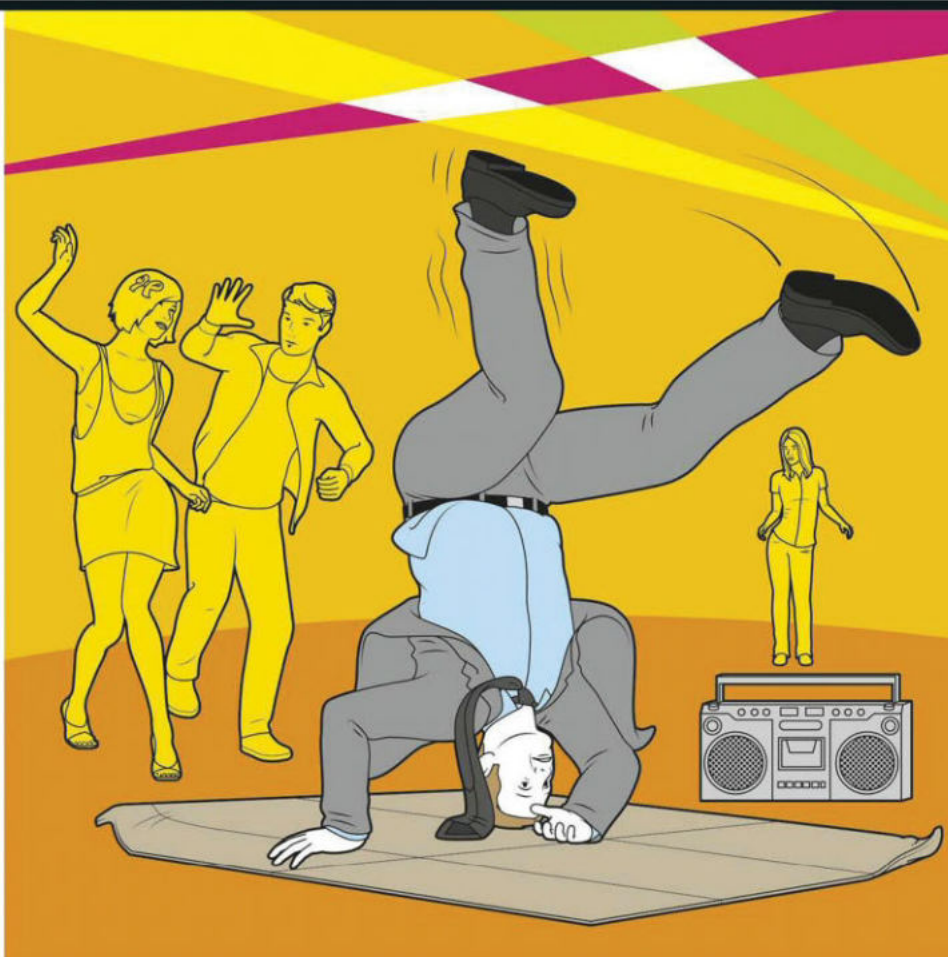


# Why do some people have rhythm and others don't?

PHIL STOKES, QUETHIOCK

Psychologists have identified three factors that contribute to differences in people's rhythmic ability: short-term auditory memory, the ability to sense a regular timing structure in sounds ('beat sensitivity') and musical training. A study of 62 people published in 2012 found that each of these factors was independently correlated with participants' ability to reproduce a rhythmic beat by tapping it out (music training was also associated with better auditory memory and beat sensitivity).

The research also showed that rather than some people having rhythm and others lacking it, there was a continuous spread of ability among the participants, from low to high. **q**



## Why are ceramics cold to touch and plastics warm?

GEOFF DUNWELL, MAIDENHEAD

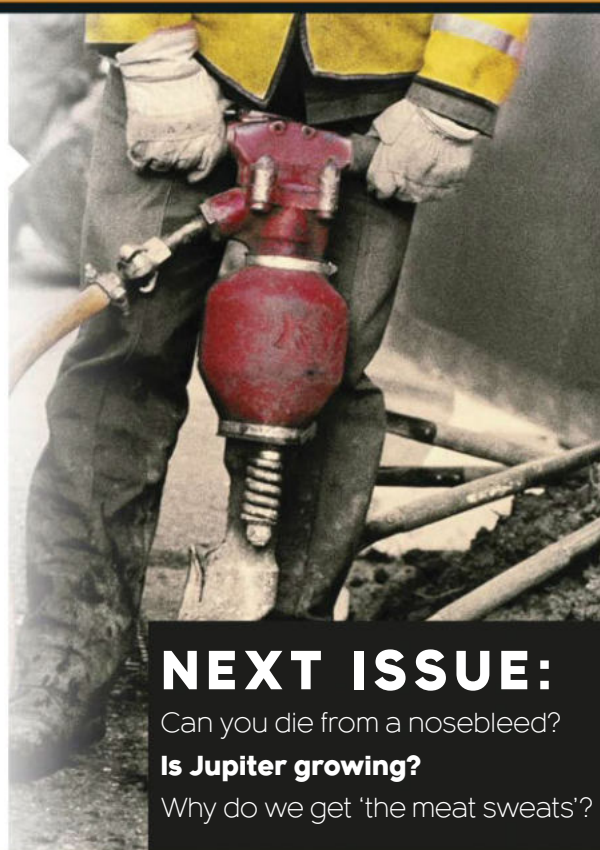
Objects feel warm or cold because of the rate and direction at which heat flows between them and our fingers. That, in turn, depends on the thermal conductivity of the material they're made of. Plastic's thermal conductivity is around 10 times lower than ceramic's. This relatively sluggish transfer of heat is what makes plastic feel 'warmer' than ceramic, even if they're at the same temperature. **RM**

## Is it possible for sound to be turned into electricity?

SAM TUTTLE, LEICESTER

Sound is made up of vibrations, and as such is a source of energy that is capable of being converted into electricity. But while, say, a pneumatic drill sounds incredibly 'powerful' to us, that says more about how sensitive our ears are.

In reality, sound energy is far more dilute than the energy packed into sunlight, and thus very hard to exploit. **RM**



## NEXT ISSUE:

Can you die from a nosebleed?

Is Jupiter growing?

Why do we get 'the meat sweats'?



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## ROBIN INCE ON... **INSOMNIA**

**“BEFORE YOU KNOW IT, YOU’RE DOSED UP ON SLEEPING PILLS WITH YOUR HEAD ON A PARSLEY PILLOW”**

**A**

s GK Chesterton wrote, “lying in bed would be perfect, if only one had a coloured pencil long enough to draw on the ceiling”. Unfortunately, our horizontal time is not spent doodling on the ceiling – it appears to be spent doing nothing.

It seems such a waste to spend one-third of our existence unaware of our existence. Fortunately, I’m an insomniac. While you are wasting your life asleep, I am swearing at the eaves, wishing I was unconscious. Avoiding sleep may increase your productivity in the short term, but it soon leads to madness, irreparable damage, and then death.

The worst example of this is those who suffer from Fatal Familial Insomnia (FFI). This extremely rare inherited brain disease is caused by a prion – a misfolded protein. Sufferers experience worsening insomnia, leading to paranoia, panic attacks, hallucinations and eventually dementia. Before death, some cases have not slept for six months.

Even light insomnia has its costs, and any slumber scientist will tell you that sleep is never wasted time (see p114). Jerome Siegel, director of the Center for Sleep Research at the University of California, Los Angeles, believes that sleep is important for conserving energy. In fact, he even suggests that a good kip is linked to the survival of the species. In ancient times, our ancestors would have had less chance of being eaten by a predator if they were snoozing inside a shelter. This also explains why we sleep less as we get older – with adulthood comes a responsibility to protect the younger and weaker.


But it gets more complex than energy conservation and lion avoidance. According to a 2000 study by researchers at Harvard’s Laboratory of Neurophysiology, sleep plays a vital role in learning. Volunteers who were deprived of sleep after receiving training for an observation test



showed no improvement in the task a few days later, unlike those who had been allowed to get some shut-eye. The scientists deduced that a big part of the learning process takes place while you’re asleep. The you-ness of you may not be in attendance, but the brain is still prepping you and perfecting skills.

Russell Foster, professor of circadian neuroscience at the University of Oxford, argues that we don’t give sleep the respect it deserves, seeing it more as an enemy than a chance for some dream-filled bliss. “In terms of time spent,” he says, “sleep is the single most important behaviour we experience.” So count each guilty siesta as a vital piece of downtime. While you are doing nothing, you are also performing vital tissue repair, consolidating memories, and processing the day’s information. I am starting to worry that I waste less of my life when I’m asleep than when I’m awake.

The more we know about the benefits of sleep, the more pressure we feel to get some, and so the cycle of insomnia continues. And once people know you have insomnia, everyone has a cure. Before you know it, you’re dosed up on sleeping pills with your head on a parsley pillow, listening to recordings of dolphins duetting with humpback whales. For better advice, I turn to Prof Richard Wiseman, whose pre-sleep tips include eating a small portion of carbohydrate-rich food, tiring out your brain with a tricky word or number game, and reducing your intake of blue light by avoiding

screen use or wearing amber-tinted glasses. And then, finally, you may sleep again. To sleep, perchance to dream... 

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage*.

**NEXT ISSUE: COMEDY AND MENTAL HEALTH**

# OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

SEPTEMBER 2016

EDITED BY JAMES LLOYD

## 01 PEER INTO THE FUTURE

### **FUTUREFEST**

TOBACCO DOCK,  
LONDON,  
17-18 SEPTEMBER,  
TICKETS  
£50 (DAY)/£80  
(WEEKEND).

Predicting the future is notoriously difficult, but it's fun to try. FutureFest, a weekender run by the innovation charity Nesta, returns this September, offering attendees a glimpse of the technologies that will be shaping our world 30 years from now.

One of the highlights of last year's festival was the Blind Robot, which used its hands to explore and build up a picture of visitors' faces. The idea was to investigate future interactions between robots and humans. This year, attendees can get interactive with Collective Reality, an installation in which up to 150 people generate sound and visuals through motion. Confirmed speakers include pioneering musician Brian Eno, writer Will Self and award-winning video game author Rhianna Pratchett.

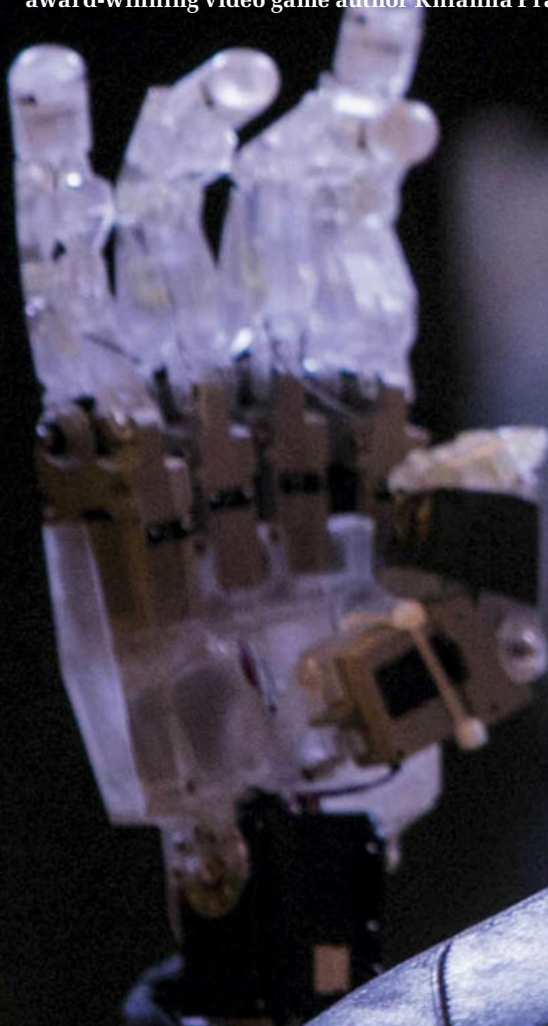


PHOTO: LOUIS PHILIPPE DEMERS



By touching the faces of volunteers, Blind Robot builds up an image of how they look



**DISCOVER MORE**

 For more TV, radio and events listings, check out #BrainFood, published every Friday on our website [bit.ly/BBCFocusBrainFood](https://www.bbc.com/focus/brainfood)

## 02

## MEET AN ICE EXPERT

This month, the North Pole could be ice-free for the first time in more than 100,000 years. We ask the UK's most experienced sea ice scientist, Cambridge University's biologist PROF PETER WADHAMS, what it might mean for our planet

**A FAREWELL TO ICE**  
**BY PETER WADHAMS**

IS OUT 1 SEPTEMBER  
 (£20, ALLEN LANE).

**Over your career, you've been on more than 50 expeditions to the polar regions. When was your first?**

That was back in 1969 when I was on board a Canadian research ship called the *Hudson*, doing the first circumnavigation of North and South America. We visited both the Arctic and the Antarctic during the same voyage. At that time there were only about 100 people in the world working on sea ice; nowadays it's the opposite – most of the world's oceanographers are working on the Arctic because we're realising what an important area it is for climate change.

**What changes have you seen in that time?**

The appearance of the Arctic has completely changed. It's as if someone has flattened an entire continent, doing away with all the mountains. In the 1970s, the ice was much thicker and older, with deep, rugged ridges. Today, nearly all of the ice in the Arctic is less than a year old – it's there in the winter months, but melts away in the summer.

**When will we see the first ice-free summer at the North Pole?**

It may be this year. The Arctic ice has a seasonal cycle, with a maximum extent around January and February, and a minimum around mid-September. This



minimum has been getting smaller, and it's looking as if this summer will be another downward jump. The official definition of an 'ice-free Arctic' is when there's less than one million square km of ice, compared to a minimum of between eight and nine million square km in the 1970s. Essentially, you'll be able to sail across the central Arctic Ocean.

**What will this mean for our planet's climate?**

The immediate effect will be to accelerate global warming, as replacing ice with darker seawater decreases the average albedo [reflectivity] of the Earth, causing it to absorb more of the Sun's radiation. This in turn melts even more ice – it's a feedback effect. The warmer winds blowing over the ice-free water will also cause the Greenland ice sheet to melt more rapidly, accelerating the rate of sea level rise.

Another concerning impact of the warmer, ice-free water is the thawing of permafrost under the seabed, releasing methane that's







ABOVE: Most of the Arctic ice melts away in the summer months

LEFT: Prof Peter Wadhams has been studying ice in the polar regions since the 1960s

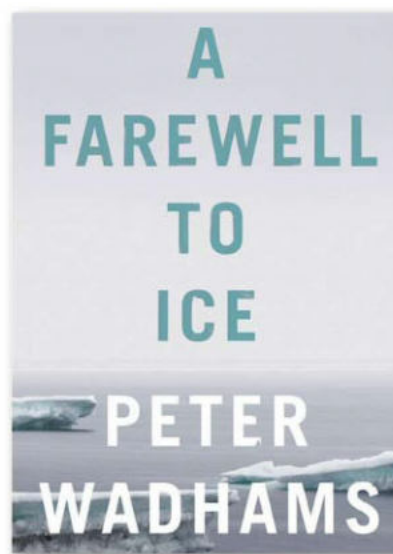
been locked up in the sediments. Scientists are already observing methane plumes in the summer months, and we've calculated that if all the methane were to be released, it could add 0.6°C to the average temperature of the planet in just a few years [the average global temperature increase between 1880 and 2012 was 0.85°C].

#### What can we do about it? Are we too late?

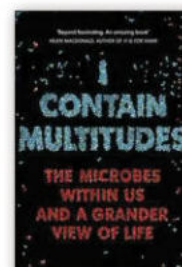
The world is warming up faster than we thought, and if we're going to prevent it from accelerating out of control we've got to reduce the carbon dioxide content of the atmosphere. That's what's causing the initial warming, and in turn the melting of the sea ice. The conventional view is to reduce carbon emissions, but we're not going to reduce them on the timescale required. Our civilisation is built on fossil fuels – how do you unmake Los Angeles?

But we're not doomed. We've got to find a way to take carbon dioxide directly out of the atmosphere. We need a major global research

programme to develop a cheap, efficient method of carbon removal – I think this should be our planet's number one research priority. Then everything else will stem from that. I'm guardedly optimistic about the future of our planet, but if we wait until the effects are really serious then it's already too late. Everything's accelerating; it's a race against time.



## ALSO OUT THIS MONTH

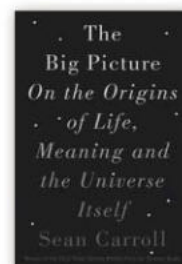


### I CONTAIN MULTITUDES BY ED YONG

Out 1 September (£20, The Bodley Head)

There are more bacteria in your gut than there are stars in the Milky Way. This

beautifully written guide to the microbes that call our bodies home explains how they protect us from disease, change our behaviour and influence our evolution.

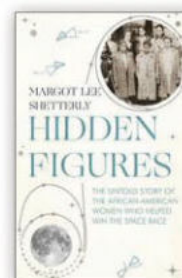


### THE BIG PICTURE BY SEAN CARROLL

Out 1 September (£18.99, Oneworld)

What is reality? Why does the Universe exist? Are photons conscious? Sean Carroll doesn't

shy away from the big questions as he attempts to get to the bottom of the origins of life and the cosmos.



### HIDDEN FIGURES BY MARGOT LEE SHETTERLY

Out 8 September (£16.99, William Collins)

Set to be adapted as a film next year, this is the untold story of NASA's African-

American female mathematicians who worked as 'human computers' during the 1940s to 1960s, calculating flight paths and playing a vital role in the Space Race.





© Mark Morreau 2016

03

**BRAIN WAVES FESTIVAL**  
POLKA THEATRE, LONDON,  
21 SEPT–2 OCT  
POLKATHEATRE.COM

## UNDERSTAND THE TEENAGE BRAIN

A spectacular, acrobatic show bringing to life the development of the teenage brain is one of the highlights of the Brain Waves festival. This fusion of neuroscience and the arts is coming to the Polka Theatre in London. In *Depths Of My Mind*, the aerialists are suspended above the audience as they explore what goes on in the brain to trigger those uniquely intense teenage emotions.

Other premieres at the festival include *Shake, Rattle And Roll*, which is a show about baby brain development specially designed to get little ones giggling and giggling, and *Bright Sparks*, a mesmerising play for children looking at how the brain's left and right hemispheres work together.

## 04 GO ON A HEALTH DRIVE

As anyone who's ever tried Googling their symptoms will know, accessing good quality medical advice can be a tricky business. Thank goodness, then, for *Trust Me, I'm A Doctor*, which returns for a new series this month.

The programme's crack team of medics – Michael Mosley, Gabriel Weston, Chris van Tulleken and Saleyha Ahsan – will again be casting their eyes over modern health trends. Are probiotics good for us? How effective is glucosamine in treating joint pain? And should we really be going gluten-free?

Meanwhile, Michael Mosley will again become a human

guinea pig, trying out a range of complementary therapies in a bid to find out what they do to our bodies. Is there any scientific truth to acupuncture, hypnotherapy, and mindfulness meditation?

Most excitingly of all, in a world first, the team joins forces with the University of Newcastle and UCL to investigate whether turmeric, and its active ingredient curcumin, could be effective anti-cancer and anti-inflammatory agents. If so, they could find their way into future treatments – as well as providing an excellent excuse to eat more curries (not that we need one!).



WATCH

BBC TWO

**TRUST ME, I'M A DOCTOR**

on BBC Two this September.

PHOTOS: MARK MORREAU,  
BBC



# JAN KONVALINKA REVEALS HIS FAVOURITE PLACES IN PRAGUE



## 1 CHURCH OF OUR LADY BEFORE TÝN

Striking 14th Century church which features the tomb of Tycho Brahe, and the oldest pipe organ in Prague. *Staroměstské nám, 110 00 Praha 1*

## 2 CLEMENTINUM

Visitors can climb the astronomical tower and can see the Baroque library hall. *Mariánské nám 5, 110 00 Praha 1*

## 3 KAROLINUM

This historic complex of university buildings dates back to the 1300s. *Celetná 561/18, 110 00 Praha 1*

## 4 ALBERTOV

This part of the city is home to many university faculties. It was at the centre of protests that led to the fall of communism in the country.

## 5 MRTVÁ RYBA

A student bar that's a popular hangout between lectures. *Benátská 4/1965, 128 00 Praha 2*

## 6 KULOVÝ BLESK

This restaurant serves authentic Czech cuisine and an impressive selection of beers. *Sokolská 13, 120 00 Praha 2 [restauracekulovyblesk.cz](http://restauracekulovyblesk.cz)*

Prague is one of the grandest European cities. It miraculously escaped damage during the wars that ravaged our continent over the last few centuries – partly because Czechs are such bad soldiers. We lost wars so quickly that there was no point in the enemy destroying the capital. Another reason for the city's unspoiled beauty is the unfortunate fact that, since the failed anti-Habsburg coup in 1618 (that eventually led to the Thirty Years' War), Prague gradually lost its political and economic importance, becoming a sleeping beauty in the European backyard.

For me, the most special thing to do in Prague is just to wander the streets and enjoy its exquisite beauty. In the heart of the Old Town, there is the beautiful **CHURCH OF OUR LADY BEFORE TÝN** 1, a Gothic jewel from the 14th Century that is the final resting place of Danish astronomer Tycho Brahe, who worked in the city with his assistant Johannes Kepler. In U Jednorozce, a neighbouring medieval building, Albert Einstein used to play violin for his friends, including Max Brod and

Franz Kafka. At the time, Einstein was professor of physics at the Charles University.

Another place that shaped the intellectual history of the city is the baroque **CLEMENTINUM** 2, which is opposite the Charles Bridge. This former Jesuit college is home to the incredible university library. The historic seat of Charles University (the oldest university in central and eastern Europe) is in medieval **KAROLINUM** 3. However, the largest university campus is located further to the south, in my favourite part of the city – **ALBERTOV** 4. Home to the schools of medicine, mathematics, physics and natural sciences, it was the centre of the student demonstration that eventually led to the fall of the communist regime in Czechoslovakia. Einstein, Ernst Mach, and Gerty and Carl Cori used to work up the hill in Viničná Street.

I like to go and have a beer in the lively student bar **MRTVÁ RYBA** 5 that started as an illegal operation in the wild 90s. However, the best beer in town is in the **KULOVÝ BLESK** 6 restaurant. 6

Jan Konvalinka is a biochemist at Charles University and the Czech Academy of Sciences.



# THE NUMBER GAMES

## GIVE YOUR BRAIN A WORKOUT

This week we have a puzzle without a known solution. I mean, we have a pretty good solution, but we don't know for sure if it is the best one possible, or which other solutions are out there.

The puzzle is to find the most efficient path through the alphabet where each letter is represented by the binary of its position in the alphabet. And 'most efficient' here means the least annoying way to paint them on your nails.

Representing the alphabet with binary digits is nothing new. Computers thrive on electrical signals where electrons are either flowing or not. So since the clandestine computers of WWII, we've needed ways to convert human-friendly letters into machine-crunchable ones and zeroes.

For a while this was done in a haphazard fashion with computer developers coming up with their own code. When the 1960s rolled around, inter-computer communications were on the rise. The most obvious binary system was set in ASCII. Here, each letter becomes its position in the alphabet, converted into a five-digit binary number. Other lead digits give you upper, lower and other cases, but the last five digits are the business end. From A = 00001 to Z = 11010.

My colleague Katie noticed that this is not the only five-digit system we have on our hands. We also have: our hands. By using two colours of nail varnish (or selectively applying a gloss or glitter) you can encode any number between 0 and 31 as binary on the digits of each hand – and therefore also encode letters, displaying a secret nail varnish message. But only to those fluent in binary. Katie set about making a



**Matt Parker** is a stand-up comedian and mathematician. He is a regular on BBC Radio Four's *The Infinite Monkey Cage* with Brian Cox and Robin Ince.

### WHAT IS MATHSJAM?

MathsJam is a chance for maths enthusiasts to get together in a pub and swap puzzles over a drink. Matt splits his time between the London and Guildford MathsJams, and Katie runs the Manchester one. Visit [mathsjam.com](http://mathsjam.com) to find your closest gathering.

YouTube video ([bit.ly/varnish\\_binary](http://bit.ly/varnish_binary)) to share this idea with the world. But showing all possible combinations of glitter (1) and no glitter (0) painted on nails is going to take a lot of nail varnish removal.

So in what order should Katie paint and film the digits on her digits? This does not seem to have been worked out before. There are already things called 'Gray codes', named after physicist Frank Gray, which try to minimise the bit-changes between successive binary numbers. These were developed back when computer switches were cumbersome physical switches, but it gives equal weighting to switching from 0 to 1 as from 1 to 0. In the case of nail varnish, it's asymmetric: it is much easier to apply varnish than remove it.

Katie decided to show the nail-glittering for all binary values from 0 to 31 (00000 to 11111). Assume all

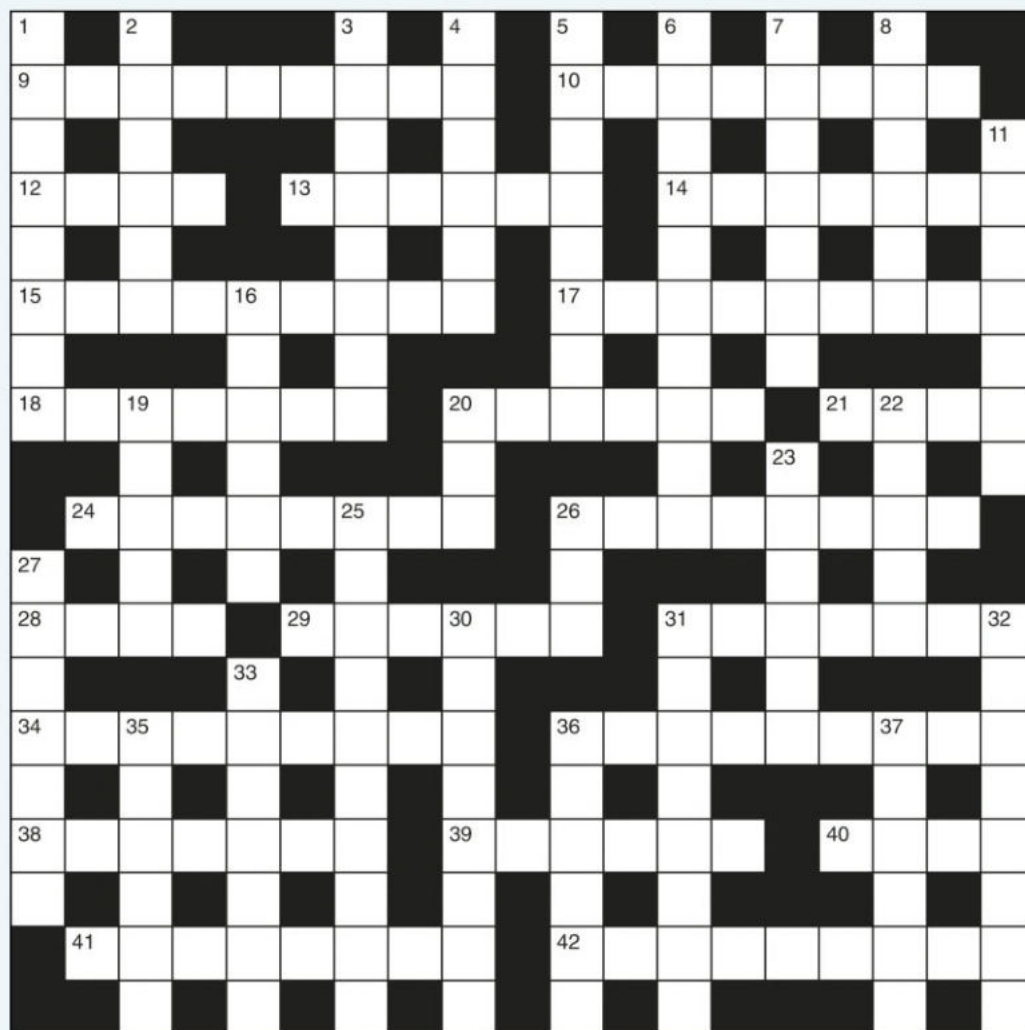
five nails start with plain varnish on, representing 00000, and glitter varnish can be applied on top of plain varnish to switch a 0 to a 1. Can you find an ordering of the numbers 0 to 31, which when you paint each successive combination on a single hand, you reach for the nail varnish remover bottle the minimum number of times? Would it have been much easier if she stuck to the alphabet, 1 to 26 only?

The current record has been set by Katie and her fiancé Paul, with a total of only 13 removals. But can you show that this is the best solution possible? Paul's thinking was pretty clouded from the nail varnish remover fumes filling their house at the time. If you can beat their solution, get in touch! [nailedit@thenumbergames.com](mailto:nailedit@thenumbergames.com)



# THE *BBC* FOCUS CROSSWORD

## BACK BY POPULAR DEMAND



### ACROSS

- 9 Cosy visit degenerates into stickiness (9)  
 10 Canada managed to take on constrictor (8)  
 12 Part of the theatre? (4)  
 13 Fatty gets round primitive instincts after impudence (6)  
 14 In the past, Luke would run about in an anorak (7)  
 15 Informant gets French to go off amphibian (5,4)  
 17 Clarities turn out to be attainable (9)  
 18 Climb points on a triangle (7)  
 20 Rubbish taken to cave (6)  
 21 Terribly neat feature of Sicily (4)  
 24 Deterioration made it difficult to get space (8)

- 26 Tune first appeared, and European was transported (8)  
 28 Tore up routine (4)  
 29 Beast has article to mail off (6)  
 31 Nonsense to have more than one such artisan (7)  
 34 Company meant to control the heavens (9)  
 36 That is taking politician to routine opposition (9)  
 38 Following directions and prosecuting (7)  
 39 Archetype of a victory by a sailor (6)  
 40 Bitterness is key to everything (4)  
 41 Pepper variety – I pot mine (8)  
 42 Military group song new to believer (9)

### DOWN

- 1 Means to get their own law (8)  
 2 Terribly pally with small lice (6)  
 3 One girl struggled in payment for decorative work (8)  
 4 About variable tennis champion, an enhanced being (6)  
 5 Monkey to stroll round repeatedly (8)  
 6 Gloomy affair of theoretical substance (4,6)  
 7 Turbulent island gets English fish (7)  
 8 Nowadays only tweak (6)  
 11 Condensation on scratch on useless digit (7)  
 16 Rod wasted weeks by river (6)  
 19 Language of a lute composition (5)  
 20 Leave a former Portuguese territory (3)  
 22 Time to arrange loan, having a key (5)  
 23 Sick doctor has initial remedy to offer (6)  
 25 Water-carrier, like Thomas (4,6)  
 26 Law-breaking implement (3)  
 27 Present academic with iron rook (7)  
 30 Sent them loan when solvent (8)  
 31 Each clip arranged about the head (8)  
 32 Bird to stalk a fish (8)  
 33 Ocean free of conflict (7)  
 35 Director's last cut is terribly unsophisticated (6)  
 36 Doomed flier takes one vehicle to America (6)  
 37 Vitamin means I can work at home (6)

### ANSWERS

Please visit  
[bit.ly/TheNumberGames](http://bit.ly/TheNumberGames)  
 for the answers to this  
 month's puzzles and  
 crossword.



# A BUYER'S GUIDE TO ULTRA HD 4K TV

**A new sharper, brighter format is coming to TV. Is it time to upgrade or is Ultra HD just a case of the emperor's new TV?** Words: Luke Edwards



Over

ver two years ago, we tested the first wave of 4K, or Ultra HD, TVs. We loved the tech, but advised caution since

there was a serious shortage of any actual content to watch. In the following years we'd hoped there would be a steady stream of new 4K content, instead we got a lacklustre dribble of YouTube videos and promos. This year, that's all about to change.

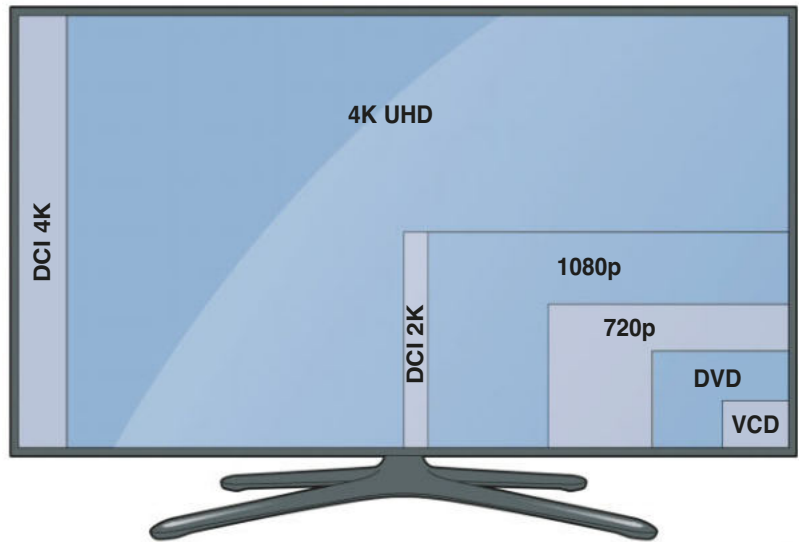
Ultra HD is coming to Sky's streaming service Sky Q with a flotilla of films, sport and TV, while Netflix, Amazon and YouTube are ramping up their Ultra HD offerings. Combined with plunging prices of screens and new, super-accurate OLED panels, the time to upgrade your TV might finally be here.

Our guide will pick apart the different technologies out there, show you how your current tech fits in and reveal the best televisions on sale right now...

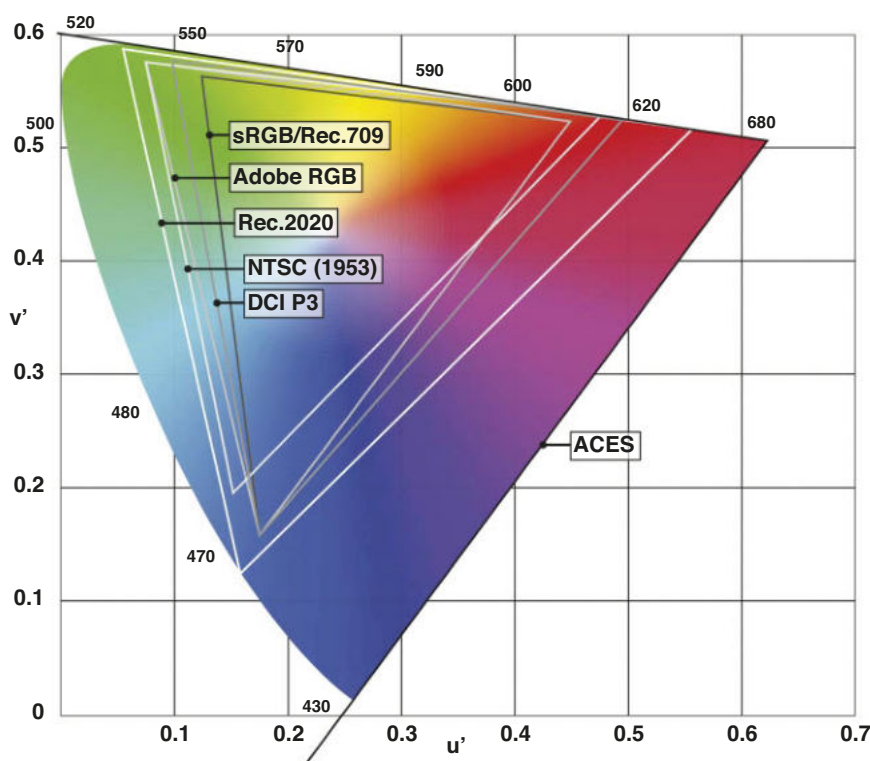
## WHAT IS 4K UHD?

At its most simple, 4K Ultra High Definition (UHD) is a measure of resolution, or how many pixels are crammed onto the television screen. 4K UHD has about four times the number of pixels found in an HD 1080p television, which has 1,920 x 1,080. On a 4K television screen you get a resolution of 3,840 x 2,160, sometimes also called 2160p or UHD for short.

The next big jump will be to 8K, but with very few examples of this working over broadcast and little content, plus even fewer televisions in the making, it will still be years before the technology becomes usable, let alone affordable.



**WHAT IS HDR?** In this colour spaces diagram, the Rec. 709 category is the colour gamut of HD TVs, whereas the Rec. 2020 category is the colour gamut of UHD TVs. ACES is used in movie production. As you can see, UHD TVs have far more colours than standard HD but there's room for improvement.



Lots of newer televisions now sport labels that boast of their abilities to display UHD 4K as well as HDR. While 4K is a resolution measure, HDR is focused on colour and light production.

HDR is short for High Dynamic Range, and refers to a screen's ability to display a wide range of colours and broad contrast variation between light and dark. The result is a more realistic image that covers a wider selection of colours.

To be classed as a true HDR screen, complete with its own sticker, a television will need to reach the standards of the Ultra HD Premium rating. This means it will have 10-bit colour. Blu-rays use 8-bit colour for 16 million colours, so this new 10-bit standard means over a billion colours can be displayed. It will also have 3,840 x 2,160 resolution – HDR TVs are all 4K UHD for resolution. It will display a minimum of 90 per cent of colours; in contrast, current TVs only cover about 80 per cent of the colour gamut. In addition, it will fit into two categories of bright and dark range, either from 0.05 nits (a measure of brightness) to 1,000 nits peak, or from 0.0005 nits black level to 540 nits peak brightness. ●

## WHAT 4K CONTENT IS AVAILABLE NOW AND HOW DO I WATCH IT?

● When 4K TVs first launched a few years ago, early adopters were limited to impressive but ultimately samey videos of the natural world. That's started to change. Not only have 4K UHD Blu-ray films and a couple of players appeared, but Netflix, Amazon and YouTube are all streaming 4K content too.

However, the 4K content that can be found on Netflix and Amazon is largely comprised of their own original shows. Meanwhile, YouTube is filled with – well – it's YouTube, you know what it's like for hit-and-miss viewing. The real turn of the tide comes from Sky Q Ultra HD, which brings over 70 feature films, live sport at 50fps and plenty of television shows all in delicious 4K resolution. The key here is easy access to quality content that makes the televisions worth the money.

UHD Blu-ray has more films appearing all the time but players are still expensive and limited in number – although the affordable Xbox One S with UHD Blu-ray player could be changing all that, following its launch on 2 August at a price of £250.

# 100

The number of gigabytes of storage capacity on a 4K Blu-ray disc.

## WILL A NEW 4K TV BE ABLE TO UPSCALE ALL MY OLD DVDS AND BLU-RAY DISCS?

In short, yes. Nearly all 4K televisions on the market will upscale to make a 1080p image look better in 4K. This is essentially done by intelligently 'filling in' all the extra pixels. The quality will vary across televisions, based on the proprietary visual engine in that device. The upscaling also depends upon the source. For example, a 1080p Netflix feed, when compressed, won't be as loaded with information as a Blu-ray disc. Some Blu-ray and DVD players will also do the upscaling, should you want.

## WHAT CONNECTORS AND BROADBAND SPEED DO I NEED IF I WANT TO WATCH 4K?

Cables, as always, mean complications. But since they're basically dumb pipes they will transmit 4K content. The key is having the correct television connectors at either end. Essentially, as long as the TV has HDMI 2.0a

## WHAT TV SHOULD I BUY?

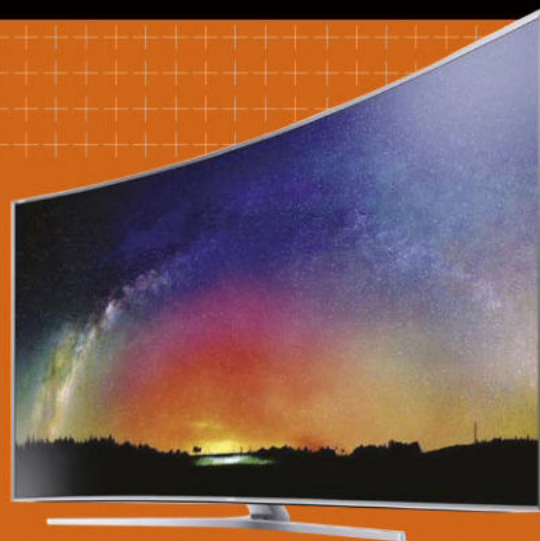
The majority of new televisions are now equipped with 4K UHD screens, with many also capable of HDR support. If you're keen to future-proof your purchase, then you'll need to look out for that 'Ultra HD Premium' label. These four televisions cover a range of budgets and requirements, but one thing they all come furnished with is 4K UHD and HDR.



### LG E6 Signature OLED

This TV is a stunner thanks to that OLED panel. Plus, you're getting all the 4K UHD and HDR compatibility from this Ultra HD Premium rated telly. OLED still, arguably, offers the best contrast ratio at the lower end for true blacks and clear cinematography. The colours have plenty of pop, and refresh rates are fast, while the OS is easy to navigate with lots of apps.

55-inch LG E6 Signature, £3,500.



### Samsung SUHD UE65JS9500

If it's LED you're opting for, meaning a lower price and higher peak brightness, then Samsung's latest Nano Crystal tech, aka Quantum Dot, should impress. Plus, Samsung's Tizen OS is app-filled and simple to navigate. While there are cheaper LED televisions out there, this is one of the best, in our opinion.

65-inch Samsung SUHD UE65JS9500, £3,200



with HDCP 2.2, then you're all set for 4K and HDR.

HDMI 2.0 can transfer up to 18Gbps which allows for 4K images playing at 50 or 60 frames per second, and transmission of colour up to 12-bit. The older HDMI 1.4 standard can manage 4K but will limit that to 24fps and will limit colour to 8-bit. HDMI 2.0a is the latest standard that has been updated to completely transfer HDR content effectively.

HDCP 2.2 (High-bandwidth Digital Content Protection) is like a digital handshake between devices that allows them to 'talk', meaning that both sides need to have the updated standard to display 4K video.

Both HDMI 2.0a and HDCP 2.2 are hardware, so make sure when you buy your television or player that it supports these latest standards to ensure you're future-proofed.

## SHOULD I BUY MY 4K UHD TELEVISION NOW, OR WAIT A LITTLE WHILE LONGER?

Now could actually be the ideal time to invest in a shiny new television. We're at a point where 4K is about to get a flood of new content for us to

8.3  
million

The number of  
pixels displayed in  
4K content.

enjoy, prices have dropped considerably and the newest HDR standard is here, so you can future-proof your purchase too.

We say it depends on what you're looking for, as that could affect how much cash you spend. Getting a 4K TV with HDR and all the connections for future-proofing can be done for under £1,000. But if you want an eye-watering, top-level screen then you'll need to spend a chunk more. OLED screens, for example, produce stunning colours, tremendous range and rapid refresh rates but they're still expensive to make. While OLED is cheaper than ever, it still costs a fair amount more than LED. Nevertheless, OLED has had serious investment from LG, which should push the price down further in the next year or so.

If OLED isn't a deciding factor, then an LED television right now is a great move. If you go for an LED television then it should keep you happy for years to come, with a display packed with smart TV functionality and compatibility for the latest technology. 📺

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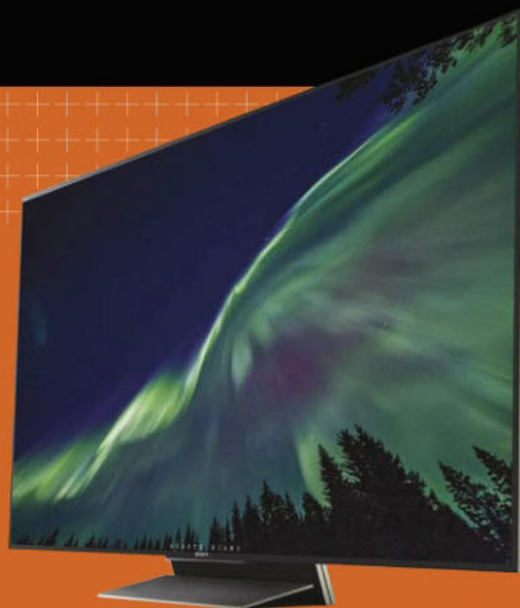
**Luke Edwards** is a freelance technology and gadgets journalist.



### Hisense 75M7900

If you want to get all the quality of a 4K screen with HDR but without breaking the bank, then Hisense is the key. This 75-inch whopper is cheaper than most 55-inch screens on the market, but it actually looks great. Quad-core processing, local dimming and plenty of smart apps make this a very tempting television indeed.

**Hisense 75M7900, £2,500.**



### Sony Bravia ZD9

Sony has pushed LED to its limits with individual LED dimming for contrast performance plus a faster processor for high-speed video without any lag. Android TV OS means apps are plentiful and smartphone interaction is simple. The ZD9 comes in a 65-inch, a 75-inch, or an eyeball-assaulting 100-inch version, with the latter costing a cool £60,000.

**65-inch Sony KD65ZD9, £4,000.**



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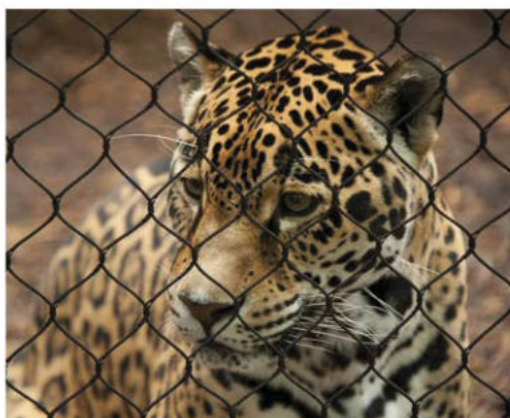
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### DO WE NEED OUR ZOOS?

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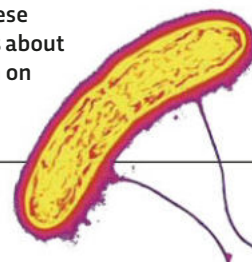


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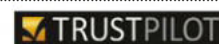
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## "Jamie Oliver had his healthy eating campaign. I think we need a healthy sleeping campaign"

Sleep expert **Prof Alice Gregory** chats to **Helen Pilcher** about her waking hours and the importance of nodding off

### **When I was little, one of my fingertips got cut off in a door.**

In hospital, they sliced off part of a toe and used it to recreate my finger. I found the fact that they could develop a finger from a toe absolutely amazing. It made me become interested in medical science.

**Then HIV/AIDS came on the scene.** I remember picking up a magazine with a mirror on the front that said: 'This is what someone with HIV looks like'. But the mirror was bent, and it distorted my face. I was petrified and told my parents that when I grew up I wanted to find a cure for AIDS.

**My career aspirations fluctuated.** Sometimes I wanted to be a scientist, other times I wanted to be a yellow taxi driver. But I never did learn to drive properly, so it was science for me.

**Although we spend a third of our lives sleeping, we don't fully understand what it's for.** Sleep is so important for kids, yet we use it as a punishment. When children do something wrong, we send them to bed. We need to educate our kids to like sleeping. Jamie Oliver had his healthy eating campaign. I think we need a healthy sleeping campaign.

**When I was a kid my parents used to battle with my sister to make her go to bed, and battle with me to make me stay awake.** One New Year's Eve they begged me to stay up because we had friends coming round, but I just wanted to go to doze off.

**I've become really interested in sleep paralysis. This is when a person is unable to move, speak or react while they are falling asleep or waking.** We've found that it's quite common; around 30 per cent of the participants in one of our studies had experienced it, but because it's not well understood or widely reported, it can be really frightening for them.

**A while ago I got an email from an American lady whose son was struggling at school.** His grades were bad and he didn't have many friends. After a lot of dead ends, she eventually got him referred to a sleep clinic where they realised he had breathing problems – it was the equivalent of being poked awake every few seconds



during the night. After treatment, his sleep improved and he became happier, made friends and got better grades. The mother knew of my work and titled her email 'thank you for your research'. It meant so much to me.

**Alice Gregory** is professor of psychology at Goldsmiths, University of London.

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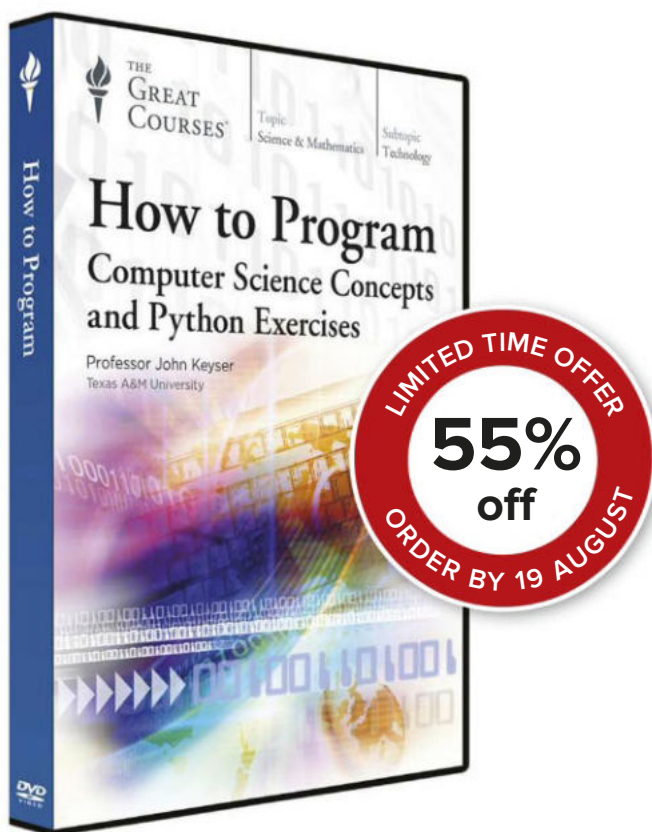
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**NEXT ISSUE: CHRIS LINTOTT**

**A bodybuilder called 'Beastie' is currently making me flip tyres, do tug of war and run with weights.** It's part of a 28-day boot camp. I'm enjoying it but it does bring back memories of being at school and always coming at the back in races.

**I worry all the time.** I worry about working too little. I worry about working too much. I don't usually lose sleep over any of it though!





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